E/CONF.39/A/137
17 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.4.3.2

United Kingdom

NUCLEAR POWER IN LESS DEVELOPED AREAS

By S.A. GHALIB, B.Sc., M.I.E.E., M.I.Mech.E.,
A.L. SHAW, A.H.W.C., A.M.I.E.E.

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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NUCLEAR POWER IN LESS DEVELOPED AREAS

by

S.A.Ghalib, B.Sc., M.I.E.E., M.I.Mech.E.

and

A.L.Shaw, A.H.W.C., A.M.I.E.E.

INTRODUCTION

1. Among the energy resources of the world, the most novel is the nuclear fuel uranium. It represents energy in a more highly concentrated form than has ever been known before. If it could be economically utilised it would be the cheapest, most easily transported fuel in the world. It is obviously of special interest to the less developed areas of the world where distances are often great, transport facilities limited and where cheap sources of power are urgently needed to raise the standard of living.

2. But to be of practical interest the methods of application of nuclear power must be well proven and commercially viable in the environment of such countries. This paper reviews the general position of nuclear power today. It describes the types of reactor that have been commercially proven and discusses the economic, financial and organisational implications in applying these to less developed areas.

3. In each country there are experts fully aware of the special problems of power generation and transmission as applied to their own environment. No attempt is made to consider in detail what this environment may be or how it varies from one country to another. It is hoped that from the discussions in this paper, the countries themselves will be able to decide whether nuclear power today may usefully contribute to their energy needs.

THE OPERATIONAL STATUS OF NUCLEAR POWER

4. Only two types of nuclear power reactor are sufficiently proven to justify commercial application now. One is the natural uranium fuelled, gas cooled, graphite moderated type "GCR" often called the "magnox" reactor, a reference to its fuel element cladding metal. The other type is the enriched uranium fuelled, light water moderated and cooled system developed in the United States of America.

It has two variants:-

(a) The "BWR" in which the moderator/coolant is allowed to boil and the steam taken to the turbines direct.

(b) The "PWR" in which it is pressurised to inhibit boiling in the primary circuit which includes a heat exchanger, to produce steam for the turbines.

5. Fig. I shows the stations in operation or under construction.[1,2] The GCR range from 30 MWE to 375 MWE output. The Calder Hall and Chapel Cross stations have been running very satisfactorily and it has been found possible to increase output from the original 37 MWE per reactor to 45 MWE. From first commissioning up to March 1962, the eight reactors in these two stations generated a total of over six thousand million KWH, earning for the United Kingdom Atomic Energy Authority a revenue of £6,000,000 from the electricity authorities in the financial year 1961/62.

6. The BWR and PWR range from 15 MWE up to 313 MWE. Of these the three plants at Shippingport, Dresden and Rowe ("Yankee") in the U.S.A., totalling over 400 MWE, have been in operation for some time; in the case of Shippingport since December 1957.

7. There are other types of reactor under construction or in operation in various parts of the world. Although some look quite promising they are not yet proven and could not be considered for commercial application in the less developed areas of the world.

8. Development of a new reactor system is a long and very costly business, so costly that only the most highly industrialised nations have undertaken it. From initial conception of a new system to entry of the first commercial station into service takes about 15 years. The less developed countries will, therefore, inevitably depend on reactor types already developed by the industrialised nations.

9. Their electricity networks are relatively small and could not accept base load units greater than 100-150 MWE. They are therefore interested in smaller units.

10. The essential difference between the GCR, BWR and PWR lies in the type of fuel. The graphite moderated type runs on natural uranium in the form of metal bars canned in magnesium alloy. Production of the metal from ore concentrate and fabrication into complete canned fuel elements involves plant of quite reasonable cost and such plants already exist in a number of the more highly industrialised countries. There is, therefore, a number of alternative potential sources of supply for natural uranium fuel elements. Perhaps the most interesting point is that any country with indigenous deposits of uranium can set up its own ore processing and fuel element fabrication plant at a cost which would not necessarily be prohibitive even for a less developed country.[3] The standards of workmanship involved are rather similar to those in light precision engineering and do not require a background of heavy industrialisation.

11. Light water moderated reactor fuel elements comprise uranium enriched in the U235 isotope to 3 or 4 times natural concentration, in the form of uranium oxide powder compressed into pellets and canned either in Zircaloy, an alloy of zirconium, or stainless steel. Enrichment is carried out in diffusion plants which are very costly and so far have only been built in the first instance to meet a military requirement. Only three countries have such plants in operation, U.S.A., U.S.S.R. and U.K. France has one under construction. Due to its military application highly enriched uranium is very closely controlled and is

not freely available. Reactors using enriched uranium, therefore, have a limited number of sources for fuel.

THE COST OF ELECTRICITY FROM NUCLEAR POWER

12. The economic characteristics of the two proven reactor systems will now be considered and compared with those of conventional types of plant. To simplify the comparisons BWR will be assumed representative of the light water moderated system.

(a) Capital charges - the GCR

13. In the gas cooled reactor using natural uranium the physical size of the reactor unit and therefore to a large degree its capital cost, is governed by the size of the uranium/graphite core assembly. There is a minimum size corresponding to a cylindrical core about 20 ft. in diameter by 27 ft. high containing approximately 30 tonnes of uranium, below which a chain reaction cannot be sustained. To allow continuous power production at any level to take place even this minimum size must be substantially increased. When it is considered that the core assembly must be contained within a pressure vessel and concrete biological shield many feet thick, it will be appreciated that the minimum size represents a substantial and irreducible fixed component of capital cost. In terms of specific capital cost it represents a significant proportion of the cost as unit size falls below about 100 MWE.

14. As shown in Fig. II at 100 MWE the cost of a GCR single reactor station would be about £170/KW and at 150 MWE about £135/KW whereas the 2 x 275 MWE units being built in the United Kingdom cost about £100/KW. This reduction in cost is due to two factors which can be deduced from Fig. III viz. increase in unit size or "scale effect" and increased performance due to intensive technical development.[4]

15. The GCR nuclear power station with construction costs lying in the range £100 to £170/KW is a high capital cost plant. But it is no higher than some hydro electric stations.

16. Assuming that sufficient capital is readily available on normal terms the chief significance of construction cost is the rate at which it is converted to capital charges per KWH sent out. For a given construction cost and loan interest rate, the capital charges per KWH are fixed by the values of amortisation period and load factor appropriate to the plant over its lifetime.

17. Because commercial operational experience of nuclear power stations is at present strictly limited and the true limit of operational life cannot be demonstrated for some years, an amortisation period of 20 years has arbitrarily been assigned to them, compared with 40 years for hydro electric stations, and 25 to 30 years for conventional thermal plant.

18. Again because there is not enough large scale operational experience nuclear station generating costs are customarily estimated on a basis of 75% availability factor, whereas operational experience now accummulating at Calder Hall, Chapel Cross and the first American stations suggests that reactor reliability would permit operation at load factors greater than 90%, and would reduce capital charges per KWH.

(b) Capital charges - light water reactors

19. The BWR and PWR are physically very much smaller than gas cooled reactors due mainly to their smaller inherent minimum core size. This is typically a cylindrical assembly of fuel approximately 5 ft. in diameter and height, although the exact dimensions depend on the U.235 enrichment level.

20. In the case of the direct cycle BWR the elimination of heat exchangers leads to a compact plant arrangement and reduced capital cost typically from £90 to £100/KW for units in the 100-150 MWE range.

21. It is also possible by using fuel of higher enrichment in U235 to reduce the inherent minimum core size. In practice it does not pay to carry this process very far. Increased enrichment results in increased cost of fuel. Therefore, a point is reached where although plant costs associated with physical size diminish with reduction in core size, both capital investment in the core fuel assembly and fuel consumption costs rise to a level which discounts these savings.

22. In small unit sizes, the direct cycle BWR costs very much less than the GCR due to its inherently small physical size. In the very large unit sizes although the capital cost differential is very considerably reduced, the direct cycle BWR is still cheaper.

23. The amortisation period of the BWR is also assumed to be 20 years, for the same reason as for the GCR.

(c) Fuel investment charges

24. The weight of fuel required for 150 MWE units would be 190 tonnes of natural uranium at about £12,000 - £16,000/te for GCR and 27 tonnes of enriched uranium at £110,000 - £130,000/te for BWR representing an investment of about £2.6M and £3.2M respectively, and leading to a unit charge of 0.055d - 0.065d/KWH for reactors in the 100-150 MWE range.

(d) Fuel consumption charges

25. Corresponding to the fresh fuel prices given above for natural uranium and for enriched fuel indicated above are net "buy back" credits on irradiated fuel of the order of £3,000 - £5,000/te and £8,000 - £10,000/te respectively.

26. The net cost of fuel consumed would therefore be about £10,000/te for metallic natural uranium with a mean irradiation capability of 3,000 MWD/te and £110,000/te for ceramic enriched uranium with an irradiation of 15,000 MWD/te. These figures correspond to a cost of heat in GCR fuel of 10d. per million Btu and in BWR of 22d. per million Btu. The GCR has an overall thermal efficiency of 33% which leads to a fuel consumption cost of 0.1d/KWH and the BWR at 30% leads to 0.24d/KWH.

(e) Operation and maintenance charges

27. Although large scale operational experience with nuclear stations is lacking, experience at Calder Hall and Chapel Cross indicates that the costs per KWH for operation and maintenance are similar to those for conventional thermal stations.

(f) Comparison of nuclear and conventional plant

28. Compared with GCR and BWR stations in the range £135-170/KW and £90-£100/KW respectively the specific capital cost of hydro electric stations varies from about £50/KW to over £200/KW. These stations have two main advantages over nuclear units of the same cost: a long amortisation period, typically 40 years, and no fuel cost.

29. Coal and oil fired stations in the 100-150 MWE range of unit size vary in specific capital cost from about £50 to £60/KW. They are, therefore, of relatively low capital cost, with a fairly long amortisation period of about 30 years and thus have low capital charges per KWH. Fossil fuel costs for major power stations range on a world basis from as low as 7d. per million Btu to as high as 70d. per million Btu corresponding to fuel consumption costs per KWH of 0.066d to 0.66d/KWH at 36% efficiency.

30. Because nuclear and hydro electric plant both tend to be of high capital cost it is important to spread their capital charges per KWH as thinly as possible by operating at the highest possible load factor.

31. In a system containing all the types of plant shown in Fig. IV the plant with lowest fuel consumption cost per KWH would be operated at the highest possible load factor consistent with plant availability.

32. Because it has no fuel cost hydro electric plant with unlimited water supply will come first with the highest "order of merit".

33. GCR with its fuel consumption cost of about 0.1d/KWH will come next followed by BWR in the region of 0.24d/KWH.

34. Finally coal or oil fired plant taking fuel at delivered costs above about 22d. per million Btu will supply the medium and lower load factor requirements of the system. Stations taking fuel at less than this cost would of course compete for order of merit with BWR and possibly even with GCR but such extremely low fossil fuel costs are exceptional.

35. Hydro electric plant with only limited water supply and therefore low availability would share the medium or low load factor demand with the high fuel cost thermal plant.

36. From these considerations it is obvious that wherever high availability hydro electric schemes can be developed at reasonable cost they will be the cheapest method of electricity generation. However in many countries water power potential is either strictly limited, too far from the centres of electricity demand or non-existent and the competition then lies between the two proven types of nuclear station and fossil fuelled plant.

37. In such cases it is obvious that except where fossil fuel costs are exceptionally low the comparison shown in Fig. IV is unfairly biassed against nuclear plant. Both GCR and BWR would claim base load priority, GCR by a particularly substantial margin, from coal or oil fired plants. In most electricity networks fossil fuel costs are high enough to ensure high order of merit for nuclear stations throughout their operational life.

38. It would therefore be more appropriate to compare nuclear plant at 90% load factor with fossil fired plant at 75% or lower. Under these conditions both GCR and BWR generating costs would compete with coal or oil at delivered costs well below 40d. per million Btu.

GENERAL ASPECTS OF INTEREST TO LESS DEVELOPED COUNTRIES

(a) Foreign currency

39. The balance of payments is a major problem in practically every country. In the less developed areas most of the heavy or complex plant must come from overseas and therefore the proportion of foreign currency inherent in each type of plant is an important consideration.[3] But it is even more important to consider the foreign currency component of the fuel cost over the lifetime of the station.

40. A country with indigenous supplies of uranium ore could, by manufacturing its own fuel, employ a GCR at a substantially lower expenditure in foreign exchange over the lifetime of the plant than either a BWR or even a fossil fuelled station importing fuel at as low as 30d/10^6 Btu.

41. The amount of local manufacture and construction depends on the stage of industrialisation reached in the country. It is estimated that the percentage of local participation in less developed countries will be in the range 30 - 50% for the GCR and somewhat less for the BWR.[3]

42. The high proportion of civil engineering work in the GCR particularly in the new designs employing a prestressed reinforced concrete pressure vessel is an advantage as much of the work can be carried out by local labour and materials.

(b) Specialised personnel requirements

43. Before embarking on a nuclear power programme it is considered that a top level team should be formed directly responsible to a Government department.[5] The team should consist of experts of a high level of technical education, experience and judgment representing the medical, physics and engineering fields. They should receive special training in health and safety matters in one of the highly industrialised countries having a large scale nuclear power programme.

44. The main function of the team would be to advise the local authorities in the siting of nuclear stations, drawing up detailed procedures on health and safety matters and taking responsibility for immediate decisions such as the evacuation of significant areas of population in the case of a serious nuclear incident.

45. The team should have at their disposal expert advice on such matters as meteorology, insurance, biology and law.

46. A typical staffing schedule for a 150 MWE GCR nuclear power station calls for staff on the following general scale:[6]

Management and technical	-	26
Clerical and general	-	34
Operation, Maintenance and Health Physics	-	147
TOTAL	-	207

47. Of these men less than three dozen require any kind of nuclear or health physics training, the remainder being of conventional power station personnel grades. Of the former no more than half a dozen of the most senior would need training more advanced than that provided by a small well balanced nuclear research centre.

(c) The role of nuclear research

48. Nuclear physics has benefits other than electricity generation to bring to less developed countries. Besides the practical application of radioactive isotopes to medicine, surgery, agriculture and industry, there is the question of original research in the academic institutes of the country.

49. Much basic and applied research connected with nuclear power involves capital investment in heavy equipment beyond the means of most of the less developed countries. Nevertheless it is desirable for the sake of the future that some of the nations best scientific brains should be exercised and developed in such fields. This could be achieved in the first instance by attachment to major research establishments in the highly industrialised countries. In general less developed countries should find it possible to lay down embryo nuclear research centres as a logical extension of the Physics Department of at least one of their universities with the object of carrying out original work in the less capital intensive fields of research.

50. There is perhaps no general rule except that each country must examine its needs for nuclear techniques and education. The education of large numbers of men to a high academic level carries with it the burden of financing the type of work in which their talents can be fully exercised. If no such provision is made the best academic brains will soon be lost to the country concerned.

CONCLUSIONS

51. Both the natural uranium gas cooled graphite moderated reactor (GCR) and the enriched uranium light water moderated reactor system, in its variants BWR and PWR, are well established in a number of countries both in numbers and unit sizes installed. The experience from the first units of each type already in operation although still limited has been very satisfactory indeed. They can be seriously considered for application to less developed countries.

52. Natural uranium as a fuel is attractive not only because of its exceptionally low fuel consumption cost per KWH but because it is financially and technically possible to contemplate setting up ore processing and fuel element fabrication plants in countries that possess indigenous reserves of uranium. But the capital cost of natural uranium reactors is nigh, particularly so in the relatively small sizes most required in the less developed countries.

53. The BWR in these sizes has a very much lower capital cost. This is due chiefly to its inherently simple nature and also to the use of enriched fuel which makes small core sizes possible. However its fuel investment and consumption costs are appreciably higher. Neither the BWR or PWR can compete with hydro power under base load conditions but in units of 150 MWE it is probable that they can begin to compete with coal and fuel oil delivered at about 40d./M. Btu and upwards.

54. Foreign currency payments are of vital importance to a less developed country. When foreign loans can be arranged covering the plant supplied from overseas and where fuel elements are manufactured from indigenous ore the gas cooled reactor can show, over the lifetime of the plant, a considerable saving compared not only with the BWR but also with conventional plant burning imported fossil fuel at 30d/M. Btu.

55. A government executive committee of highly qualified professional men drawn from medical, physics and engineering fields should be established before a nuclear power programme could be launched.

56. A staff of 200 would be required to run a 150 MWE (GCR) nuclear station. Of these less than 30 would need to have nuclear or health physics training and in only six cases would this have to be highly specialised. The remaining 170 would be drawn from conventional thermal plant operating personnel grades.

57. Much basic and applied nuclear research is too costly for the less developed countries. Embryo nuclear research centres could however be set up as logical extensions of the universities.

58. The number of men trained to a high academic level must be related to the provision of work in which their talents can be fully exercised.

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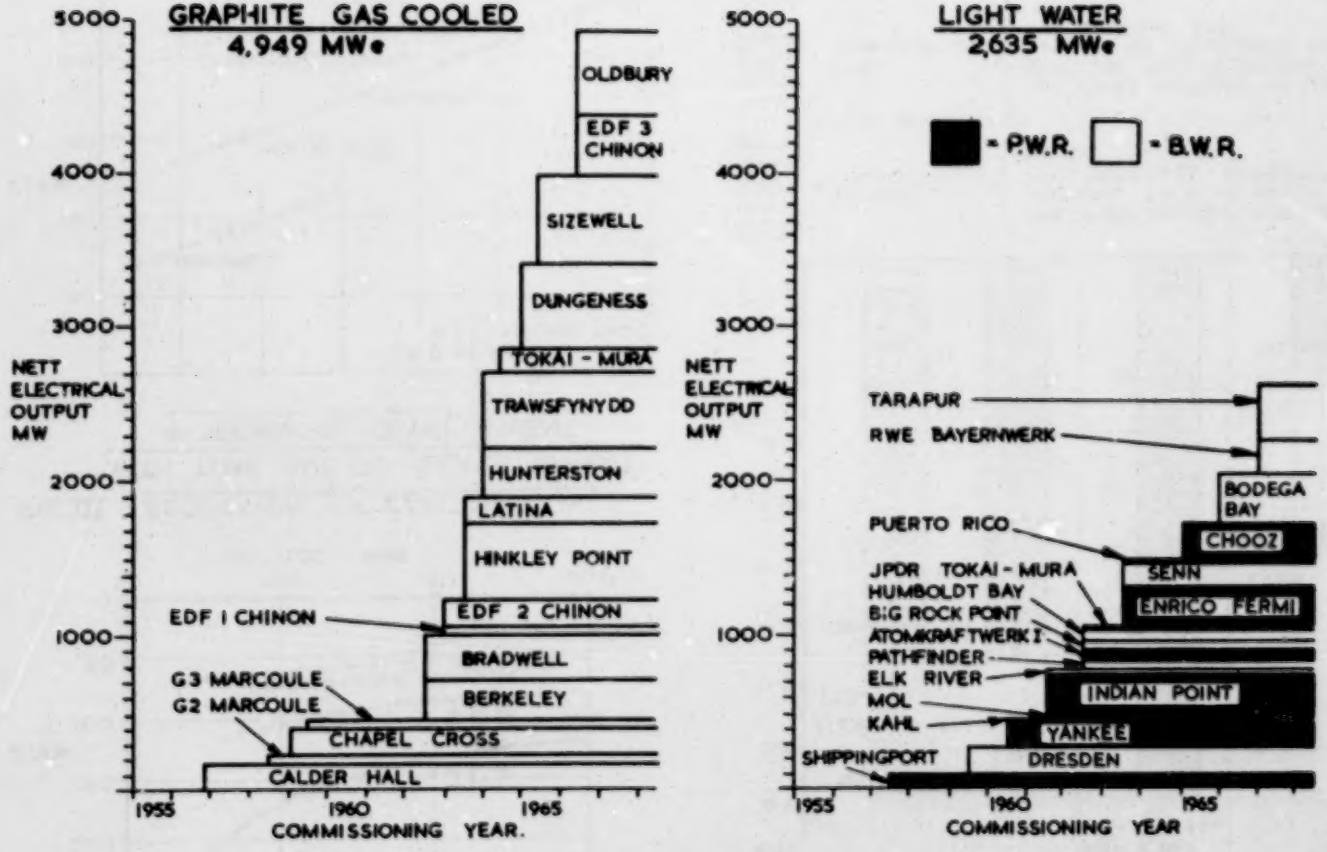


FIGURE I

NUCLEAR STATIONS OPERATING OR UNDER CONSTRUCTION.

FIG II SPECIFIC CAPITAL COST V UNIT SIZE FOR SINGLE REACTOR STATIONS.

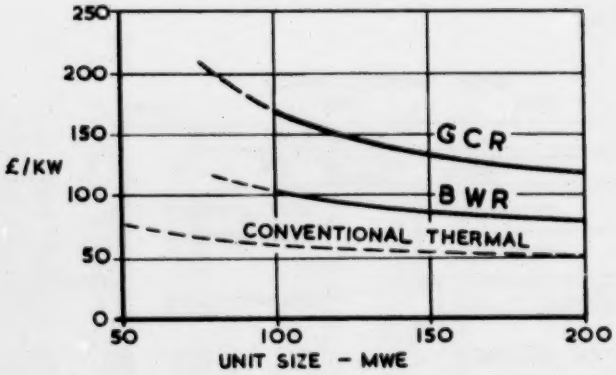


FIG III REDUCTION OF CAPITAL COST WITH TIME DUE TO SCALE EFFECT + TECHNICAL DEVELOPMENT

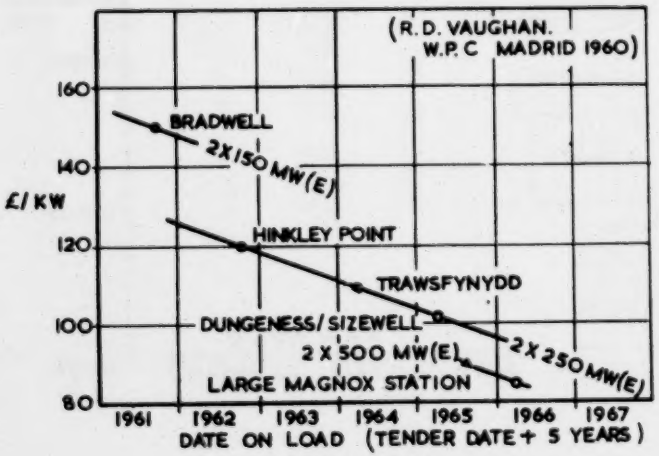
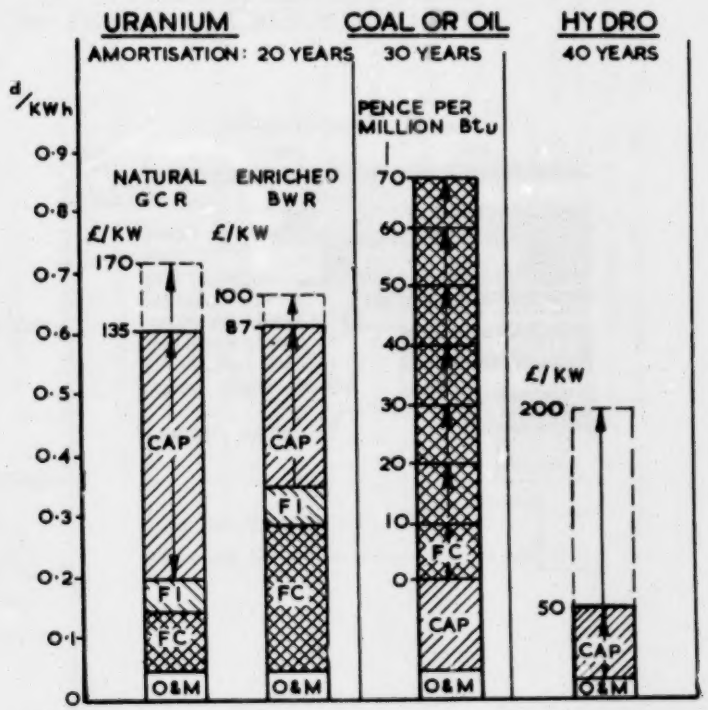


FIG IV TYPICAL GENERATION COST RANGES.

BASIS :- 5½% INTEREST 75% LOAD FACTOR



NOTES

CAP = CAPITAL CHARGES. — THE CHIEF VARIABLE FOR NUCLEAR AND HYDRO STATIONS, EACH OF WHICH IS SHOWN AT TWO EXTREMES EXPECTED IN 100-150 MWE RANGE

FI = FUEL INVESTMENT

FC = FUEL CONSUMPTION — THE CHIEF VARIABLE IN COAL OR OIL FIRED STATIONS, AND IS SHOWN FOR VARIOUS VALUES OF DELIVERED COST UP TO 70d PER MILLION Btu

O&M = OPERATION & MAINTENANCE — TAKEN ARBITRARILY AS 0·05d/KWh FOR NUCLEAR, COAL AND OIL AND 0·03d/KWh FOR HYDRO.

1079 E - Oct.1962 - 1,600

E/CONF.39/A/138
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Agenda Item: A.4.2.3

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DESIGN, ERECTION AND OPERATION OF SMALL REFINERIES IN DEVELOPING COUNTRIES

By K.L. HAGEMANS,
R.E. INGALL

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DESIGN, ERECTION AND OPERATION OF SMALL REFINERIES IN DEVELOPING COUNTRIES

by

K.L. Hagemans
R.E. Ingall

INTRODUCTION

1. The past ten years have seen a basic change in the pattern of development of refinery capacity. There is now a strong tendency to construct small refineries located in the consuming areas rather than to expand the existing large export refineries.

2. These new refineries are frequently located in developing countries, whose initial refined product demand is small and relatively simple since industrialization has not yet become a major factor in the national economy. Once the refinery has been constructed it tends to become the nucleus for industrial development in the country. Conversely, the development of the petroleum industry is stimulated by industrial growth.

3. It is essential both to the country in which a refinery is to be located and to the sponsors of the venture that a refinery of optimum size and type is built in the most suitable location, yielding in an economically viable manner the product pattern which most clearly matches the country's market demand.

4. This paper will follow the development of a typical refinery design highlighting the various problems which occur and have to be solved.

DESIGN

Product Demand Evaluation

5. The first problem encountered when considering a refinery in a new location, particularly in a newly developing country, is to determine the local product demand pattern both quantitatively and qualitatively. Demand is usually limited to the main products, viz. gasoline, kerosine, diesel and fuel oil, which can be obtained from most crude oils. However, the proportions of the various products required by the market rarely match the products that would be obtained from the simple processing of a single crude oil. This difficulty can usually be overcome by a selection of appropriate crude oils, which when supplied in the correct proportion to the refinery can closely match market requirements after simple processing. Some of the flexibility inherent in crude allocation is illustrated in Table 1.

Table 1

Flexibility in Product Output by Varying Crudes Intake

Basis: Simple Refinery	Crudes processed	
	100% Kuwait	50% Seria 50% Basrah
Yields of Products - weight %		
Motor Gasoline	18	29
Middle Distillate	23	41
Fuel Oil	59	30
	100	100

6. The same range of yield variation from a single crude could be achieved by building more complex refining and processing units, such as catalytic cracking, alkylation, isomerisation and visbreaking units, etc., which are termed secondary processing units. However, experience has shown that these secondary processing units are expensive to construct and can seldom be justified economically until some considerable time after the refinery start-up. Their construction should therefore be deferred until they are required. This results in the construction of simple refineries with few processing units and auxiliary facilities and consequently initially low capital and operating costs.

7. Nevertheless, it would be coincidental if the region for which the refinery is planned could initially absorb the entire range of products obtained from the available crude oils. Therefore, in many cases surpluses of products will occur during the initial period of operation and have to be shipped out of the area in order to find a profitable market. Also, it might be necessary to balance market demand by marginal imports of deficit products. Such movements can, of course, be very expensive and it is therefore desirable that they should be kept to a minimum.

Determination of Refinery and Processing Unit Capacity

8. Once it has been decided that a refinery is to be constructed in a certain country, the economics of the venture are studied on the basis of a number of individual refining schemes in which the supply of the crude oils or crude blends play an important part. Based on these studies the capacity of the refinery and the size and type of its processing units are determined, as warranted by the current market demand pattern of the area to be supplied by the refinery, consideration at the same time being given to the possible future extensions to meet the demands of a growing economy.

9. Governed by these considerations, the largest possible capacity for the processing units is aimed at, since it is well known that the larger the unit, the less it costs to run per unit of intake. The impact of size on the operating costs of typical simple refineries is shown in Table 2.

Table 2

Relative operating costs of various size refineries

Basis: Simple refineries without secondary processing facilities operating at full capacity

Size of refinery tons per annum	Relative costs of processing 1 barrel of crude oil
500,000	228
1,000,000	161
2,000,000	122
4,000,000	100

10. However, set against the low unit operating costs of the large refinery are the higher initial investments and, possibly even more important, the necessity of uneconomic transportation of surplus products to a point where they can be utilized. Therefore, it is important that the forecast of market demand should be

realistic in order that the refinery can be sized to meet it without having excessive idle capacity. The effect of idle refining capacity on the cost of processing one barrel of crude oil is shown in Table 3.

Table 3

The effect of idle capacity on unit operating costs

Basis: A simple refinery processing Kuwait crude oil

Percentage of refinery capacity idle	Relative costs of processing 1 barrel of crude oil
nil	100
10	109
20	118
30	129

11. As in so many phases of refinery planning, the capacity initially established for a new refinery and those of the processing units, even when the basic market requirements are known, represent a compromise and, as will be appreciated from the foregoing, are governed by economic and financial considerations closely related to the development of the country in which the refinery is to be built.

Refinery Processing Equipment

12. From experience, on the basis of initial market product requirements in developing countries, both quantitative and qualitative a more or less standard pattern for refinery development has evolved. It has been found that in the majority of cases a refinery consisting initially of a crude distilling unit and a catalytic reformer usually covers these requirements, if a low-sulphur crude is available. However, if a high-sulphur crude, such as Middle East crude, must be processed, a desulphurizing unit should be included.

13. The crude distilling unit produces gas and components for gasoline, kerosine and light and heavy fuel oils.

14. The catalytic reformer transforms the low-octane gasoline components into high-octane gasoline components. Thus even from the outset a refinery comprising a crude distiller and catalytic reformer is capable of producing an adequate number of components, which when blended in appropriate ratios will produce a comprehensive range of products closely matching initial market demands. By keeping the units initially to be installed in the refinery as simple as possible a favourable influence is obtained not only on construction costs but also on the overall operating costs.

15. However, as the economy of the country develops a demand may be created for more specialized products, for example liquid petroleum gas (LPG), bitumen, jet fuels and high-octane gasolines, and at that stage further additions to the original simple refinery scheme may become justified and a refinery development scheme as shown in figure 1 (attached) could be visualized. These additional processing facilities may consist of a hydrodesulphuriser, a catalytic cracking unit, an isomerization unit, a visbreaker, etc. It should be realized, however, that when the complexity of the refinery increases the operating cost per unit of intake will also increase, as illustrated by Table 4.

Table 4

Relative operating costs of refineries of varying complexities

Type of refinery	Relative operating costs of processing 1 barrel of crude oil
a) Crude distiller plus platformer	100
b) Same as a) plus a hydrodesulphurizer	113
c) Same as b) plus bitumen plant	116
d) Same as c) plus catalytic cracking complex	172

16. It should be emphasized here that some of these additional processing facilities, besides being expensive to operate, are also expensive to build. Therefore, the additional heavy investment should be delayed until an economic level of demand for their products is established.

Site Selection

17. Once the economic desirability of a refinery has been established and the capacity of the refinery and the size and type of processing units required determined - both for the initial project and for possible future extension - and once the amount of tankage and the area of land required have been established, a site survey is undertaken. During this survey the many factors governing the overall economics of the project and peculiar to each possible location is studied and compared. The most important of these are:

crude handling costs; product distribution costs; availability of road and rail connections; availability and costs of services such as power, cooling water, local labour, workshops, housing and the like; nature of the site; and air and water pollution.

(a) Crude handling costs

If the crude oil has to be supplied from overseas, which is usually the case, the most economical location for the refinery, from both the crude-handling and the product-distribution point of view - especially if coastal trade is involved - is normally on or close to the coast. In this case the facilities provided for handling the crude oil and products consist of jetties or buoy moorings, the latter generally being used if the water depth close to the shore is inadequate for large tankers. Usually, these facilities are planned to handle the largest size of crude carrier that can be economically justified. Here again a compromise has to be struck between possible facilities required in the future and the target of keeping the cost of the basic project within economic limits. Thus it might well be possible for the handling facilities to be planned for the maximum economic tanker size whilst other facilities, such as the receiving tankage, pumps, etc. will be staged in so far as this can be economically justified. It should be noted that if owing to certain circumstances the refinery has to be

built some distance from harbour facilities and marketing distribution installations, the economic penalty is disproportionate to the distance involved, i.e. in the case of the connecting pipelines not only their length, but also their diameter increases.

(b) Product distribution costs

Within the planned supply area of the refinery, the products can be transported from the refinery to the consuming centres by road, rail or sea or a combination of these.

The study for determining product distribution costs for the various alternative sites must take into account such factors as freight charges for the different modes of transport, the possible purchase of transport equipment, the quantities involved and the distances to centres of consumption, as well as the availability of roads, railways or waterways. Product distribution costs are a major item of expenditure and might jeopardize the overall economics of the project. Other costs for the alternative refinery sites being equal, product distribution costs have often been decisive in locating the refinery.

Normally, it is found that the most economic location is in or near a main consumption area, which usually embraces a deep-sea harbour around which economic development has already taken place.

(c) Availability of road and rail connections

If there is a marketing distribution installation in the vicinity of the refinery, which is provided with railway facilities, it is not always initially essential for the refinery to have a rail connection. The marketing installation can be connected by pipelines to the refinery and in a sense forms part of the refinery as far as tankage and rail transport are concerned, which has a beneficial effect on the overall cost of the project. Nevertheless, a rail siding alongside the refinery can be an asset during the refinery construction phase for the delivery of equipment and materials.

As soon as bulk LPG and bitumen facilities are added to the refinery, the provision of a rail connection becomes of increasing importance. As will be appreciated, good road connections are essential not only for the distribution of products by road but also for getting equipment and personnel to the site.

(d) Availability and costs of services

Where possible, the refinery, in those facets of its activities not specifically concerned with oil refining techniques, makes use to the greatest possible extent of the services which can be provided by others, provided, of course, that they can be supplied at competitive cost. The main services concerned are the supply of electricity and water, maintenance work to be performed in local engineering works, skilled labour during overhauls, housing for staff and labourers, etc., all of which should be closely studied as they may have a bearing on the siting of the refinery.

(e) Nature of the site

With the aid of topographical maps the nature of the alternative sites is examined and the amount of excavation and filling determined that will be necessary to develop the site. In addition, the suitability of the various sites for the construction of tankage and processing units is established. This is normally done by carrying out soil-boring tests to determine the type of foundations, the length of piles (if required), the type of drainage system, etc.

In theory, a refinery can be built on almost any site, for example on reclaimed or even hilly ground. However, it should be kept in mind that poor soil conditions necessitate extensive piling, foundations and drainage, which may increase the cost substantially. Similarly, a site which is irregular in shape or contour can also be expensive to develop if excessive earth-moving is involved.

The most favourable site would be a relatively flat piece of land with good soil-bearing properties, sloping gradually to a big waterway or to the sea, facilitating the drainage of the site.

(f) Air and water pollution

The elimination of nuisance from air and water pollution is a basic consideration in the siting of any refinery. The main possible sources of pollution are:

vapours released from crude oil and light product tankage; leakages from process equipment; stack gases; refinery flares; treating plant effluents; oily water effluents.

The abatement of air and water pollution has been the subject of studies for many years and it can be stated that as a result of these studies and the experience gained, pollution from the above potential sources in modern refineries is no longer a problem. With the introduction of floating roofs on crude and light product tanks the release of vapours can be almost entirely eliminated. Good housekeeping prevents the release of vapours from leakages in process equipment and the use of an efficient relief gas and liquid-disposal system can reduce air and water pollution to a negligible level.

Any obnoxious waste gases from processing units are burnt in the process furnaces and thus converted into harmless compounds, which can safely be disposed of in the atmosphere, together with the stack gases.

The use of efficient fuel burners in process furnaces and boilers and elevated stacks for adequate dispersion of combustion gases can effectively control air pollution from these sources.

Refinery flares of modern design, incorporating efficient combustion systems, are not a source of air pollution.

Treating-plant effluents in the form of spent chemicals, which used to be a problem in conventional treating plants, such as acid, caustic and doctor treaters, have now virtually been eliminated by the application of modern refinery processes, e.g. the hydrodesulphurizing process.

Efficient oil/water separators for treating refinery effluent water have been developed. It is worth noting that since the introduction of air-cooled equipment not only has the availability of large quantities of fresh or salt water for cooling purposes ceased to be the critical problem it used to be, but also the amount of possibly oil-contaminated water has been reduced considerably.

Over the years considerable strides have been made towards the virtual elimination of air and water pollution and it is possible nowadays to design refineries so that any community in the vicinity will not suffer from either air or water pollution.

Process Design and Engineering

18. Having decided where the refinery will be built, what units it will include and the capacities of the individual units, the next stage of development is the detailed process design and engineering.

19. With the construction of small refineries coming more prominently into the picture, studies were undertaken to determine how the capital and operating costs of refineries, including manpower requirements, could be reduced so that even small refineries could be made economically acceptable. As a result of these studies, in which latest technical developments in the petroleum industry are incorporated, rational or economy design concepts evolved. When applied, they satisfy these requirements without infringing on safety and operational reliability. Some of these concepts, which fall within the various cost-saving categories, entail:

- Maximizing energy savings and heat recovery by integrating processes and utilizing heat from furnace flue gases for steam generation.
- Using, where possible, air cooling instead of water cooling.
- Using very reliable equipment of high efficiency and simple design, thus obviating the need for stand-by equipment, e.g. for pumps, compressors, exchangers, electrical distribution system, etc.
- Applying internationally accepted codes to the petroleum industry instead of local ones which are often not specifically based on refinery operations.
- Having compactly built and fully integrated processing units, utilities, blending and storage facilities with one central control station and a single administration building with an annex for combined workshop and stores.
- Introducing in-line blending and product-quality measuring instruments in process units and tank farms.

20. These are just a few of the concepts leading to savings in capital and operating costs, but added together they show a substantial saving not only in these costs but also in manpower requirements.

21. In the process design stage, detailed flow diagrams for the refinery and individual processing units are prepared. Based on the available process data, the major equipment is dimensioned.

22. Engineering covers the stage during which all drawings are made according to which the refinery is to be built, and incorporates mechanical, civil and electrical designs. Furthermore, the specifications for purchasing the materials and equipment are drawn up. It is at this stage of the project that use should be made of the most modern techniques and up-to-date knowledge.

ERECTION

23. On the basis of the drawings and material and equipment specifications prepared in the design and engineering stage, the materials required to build the refinery are purchased. Where possible, materials of local origin are used. When selecting vendors, both prices and delivery times play an important role, as the time of arrival of the materials at the site has to fit in with the erection schedule.

24. Before the actual erection of the equipment can be started, a tremendous amount of civil work has to be performed, such as clearing and levelling of the site, building roads, installing underground drainage and electrical cables, preparing foundations, etc.

25. After part of the civil work has been completed and the necessary materials have arrived at the site, the erection of the equipment, tanks, pipelines, etc. can be started. Depending on location, weather conditions encountered, etc., the time required to construct a small refinery varies between 18 and 24 months, whilst that for the overall project may vary between 24 and 30 months. The skilled and unskilled labour required to perform this work, which may number a thousand men when erection is in full swing - even for a small refinery - is engaged, where possible, on the local labour market. Selected semi- and unskilled labourers usually receive training at the site under the supervision of experts engaged locally or brought in from abroad prior to being engaged on actual erection activities.

26. During the entire construction period, extensive use is usually made of the most modern erection equipment, tools and techniques.

27. As will be apparent from the foregoing, this phase in the realization of the project demands intensive planning and scheduling in order to ensure that the erection is completed within the time set and moreover is executed in the most efficient and economical manner.

OPERATION

28. Within the concept of a refinery, activities can broadly be sub-divided into those connected with the processing and handling of crude and products, with the maintenance of the refinery installations and with administration.

29. The operation of the processing units, utilities and oil movements are on a 24-hour a day basis. In order to control the process conditions of the operating units they are equipped

with automatic control instruments which are all concentrated in one central control station. These instruments enable the operator to follow changes in operating conditions as they occur and also, if necessary, to reset the operating conditions by remote control. The activities in this control centre may not only be confined to these alone but may also include others, such as blending of components into final products - in which case extensive use is made of automatic measuring and product analysing instruments - remote tank gauging, product handling, etc.

30. All these operations are usually supervised by one person who is assisted by operators and helpers to whom specific tasks and responsibilities are assigned. The number of operators required varies and is entirely governed by the complexity of the refinery.

31. Concentrating as many activities as possible in one-control centre will be beneficial not only to the efficiency of operations but also to manpower requirements and consequently to the operating cost of the refinery.

32. Besides the operators in processing units, etc., highly qualified personnel, usually with university degrees, are needed, responsible for the overall planning and supervision of operations.

33. Closely related to the operational activities are those of the laboratory. In the laboratory, equipped with special apparatus, tests peculiar to the components or products are carried out and provide a check on operations. When automatic analysers are used in the control centre, they take over some of the laboratory's duties.

34. In order to keep the refinery in an operable and safe condition between major overhauls, day-to-day maintenance has to be performed on parts of the various installations, such as on instruments, pumps, heat exchangers, pipelines, etc. This maintenance work is planned and scheduled from day to day and under normal operating conditions during the day shift maintenance will usually only have to be done. However, during a major turnaround, maintenance is often done on a 24-hour a day basis to reduce the off-stream time of the refinery.

35. For this work skilled craftsmen such as welders, pipefitters, machinists, instrument technicians, etc. are required, who usually work under the direct supervision of foremen, whilst highly qualified and experienced maintenance personnel are entrusted with the overall responsibility. The number of maintenance people permanently on the refinery's payroll is entirely determined by the extent to which local industries can supply the necessary assistance. This is of special importance for turnarounds on processing units fully integrated which have to be shut down together. If these services are available, use will be made of them to the greatest possible extent, enabling the refinery to maintain a smaller maintenance force.

36. Personnel experienced in refinery operation and maintenance are required to man a refinery. This applies particularly to the operational personnel who have daily to cope with

inflammable materials. If personnel with this specific experience cannot be found locally, it will be necessary for local works to be given an extensive training commencing well in advance of the start-up of the refinery. Key personnel might even have to be trained in other refineries abroad in order to prepare them fully for their future task. Besides the personnel directly involved in the operation and in maintenance, there is a small group which is more concerned with the future than with day-to-day problems and prepares plans for improving refinery efficiency or economics.

37. The administrative activities mainly centre around accounting, purchasing, materials and personnel, and usually do not differ significantly from those in any commercial enterprise.

38. Though conditions may differ considerably from country to country and assuming that public services can be rendered to the refinery, the total manpower requirements for a small domestic refinery will be from 100 to 200 people.

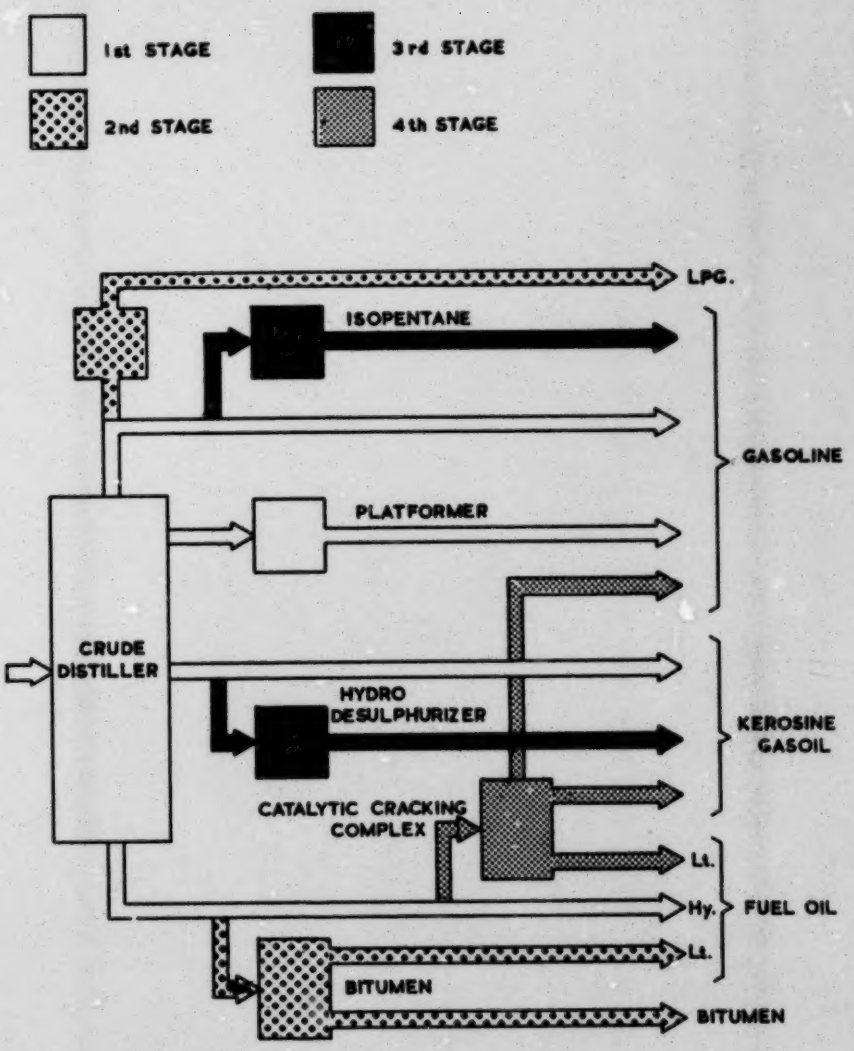
CONCLUSION

39. In the foregoing a comprehensive review has been given not only of the factors influencing the viability of a small domestic refinery in a developing country but also of the various measures which have made the small refinery economically possible.

40. As will be appreciated, it is quite impossible to express in terms of money the savings which can be obtained by each individual concept or combination, owing to the complexity of a refinery. Moreover, they may vary considerably from country to country and are further influenced by material and labour costs and the availability of public services. However, it can be stated that nowadays it is possible to build a small domestic refinery with an intake of say 20,000 barrels crude oil daily (1,000,000 metric tons per year) for 30 to 40 per cent. less than a few years ago.

FIGURE 1

DEVELOPMENT OF SMALL DOMESTIC REFINERIES BY STAGES



1075 E - Oct.1962 - 1,600

E/CONF.39/A/139
18 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.1.2

Japan

ESTABLISHMENT OF A TRAINING CENTER FOR SURVEYING AND MAPPING

By TOYOZO OKUDA,
Geographical Survey Institute

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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ESTABLISHMENT OF A TRAINING CENTRE FOR SURVEYING AND MAPPING

by

Toyozo OKUDA, Director, Geographical Survey Institute, JAPAN

1. At the past three United Nations Regional Cartographic Conferences for Asia and the Far East, it has been discussed the necessity of establishment of a regional training centre for surveying and mapping among the countries in the ECAFE region. Analysing the previous discussions, the followings will be pointed out:

   (a) Although the requirements were expressed for setting up a regional cartographic organization among the countries concerned, it was felt that it would be rather difficult to establish a big organization involving a huge amount of expenses and a large number of staff members.

   (b) Comparing the necessity of setting up a cartographic organization with a training centre for surveying and mapping, the latter would be much more important and desirable.

   (c) Although the urgent need of setting up a regional or sub-regional training centre will not be neglected, the national or domestic training centre of each country should be filled up in quality or in facilities and staffs.

2. It is needless to say that in order to accomplish speedy and promptly the economic and social developments, aerial photographs would be very helpful as a basic material. Therefore, almost all countries in the world have utilized aerial photographs for the planning of those developments. Unfortunately, however, extreme shortage of the specialists on aerial survey (both of photogrammetry and photo-interpretation) has been strongly pointed out by many countries. Even some of the advanced countries in this field feel it. In this respect, the training of specialists and instructors will be urgently required.

3. On the other hand, we know that not so small number of trainees have been sent to the specialized institutes or training centres for surveying and mapping. Unfortunately, however, it happens that many of them have frequently been promoted to higher ranks and sit down on arm-chair after coming back to their home countries in less developed areas. In such status, it would not be expected to train technicians or specialists by them. Foreign instructors are often invited for training particularly in these areas.

4. Considering such situations, we would like to propose as follows:

   (a) Sub-regional training centre should be set up by utilising the facilities of the domestic training centre and adding the sub-regional characteristics to it.

   (b) Such centre should be financially assisted by the United Nations.

   (c) The training centre should start with simpler field like photo-interpretation.

5. Realising the above items, necessary experts will be exchanged among the countries by the financial assistance of the United Nations. The equipments and the facilities of the domestic centre are commonly used to train the trainees from other countries.

6. Realising the idea of the United Nations, we have the pleasure to take part in such sub-regional training program for which we would like to expect the United Nations' assistance.

1012 E - Oct.1962 - 1,600

E/CONF.39/A/140
18 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.5.2.1

United Kingdom

MINING EXPLORATION METHODS

By P.A. RANKIN,
D.F.C., A.R.S.M., B.Sc., A.M.I.M.M., F.G.S.

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MINING EXPLORATION METHODS

by P.A. Rankin, D.F.C., A.R.S.M., B.Sc., A.M.I.M.M., F.G.S.

Introduction

1. Mining to many signifies the extraction of somewhat uncommon metals or minerals such as gold, copper, nickel, lead, aluminium, diamonds, asbestos, iron, coal. To those who live in rather special geological areas, mining means the business of extracting one particular metal or mineral, e.g. gold in Ghana; tin in Nigeria, Malaya and Indonesia; uranium in the Congo; copper in Katanga; bauxite in Guiana; lead, zinc, silver or rubies in Northern Burma. Such a situation has given rise to wealth in a broad sense of the word to the area concerned. However, it and the mining laws it has brought about, has some times cause a narrow local view on exploration. It is appropriate to take a new look at those areas where mining and exploration methods have become traditional through the structure and policy of private enterprise mining corporations who deal in selling ore to world markets and to the mining and exploration laws of the country concerned which may be in need of revision.

2. A government, in a less developed area, honestly trying to use its country's own natural resources to the benefit of its own country folk, will be attempting to obtain a knowledge of the kind and quantity of its natural resources in order to diversify its economy. In the field of mining it will be assessing the value of the deposits which are being and can be mined in terms of export and of value to the people themselves - work, money, energy, level of living, health. It will be justifiably perturbed if its mineral economy is virtually mono-mineral (or metal) and will be concerned to diversify its mining.

The Concept of Systematic Mineral Exploration

3. It can be assumed now that chance discovery of ore can be ruled out of any exploration plan or policy. If it occurs, and it is still possible in some parts, it will be good luck; but exploration policy should not be conditioned by such a possibility. A systematic search for ore is the basic concept for the future by Government. "Ore" should be considered in the widest possible sense. "Ore" is any naturally formed substance extracted from the earth which is of use to mankind. It, therefore, embraces metals; sedimentary materials such as coal, peat, oil, phosphates, salt, clays and the like; quarried stone, slate, limestone, road and building materials. It may be found not only on land but also under lakes and under the sea. To be practical at this present time, sea areas are defined as those being close to the shore, within

practical depths of water and thus within territorial limits.

Choice of Area

4. The starting point for systematic mineral exploration is the choice of an area in which to begin. This choice is made from a consideration of (a) the general type of ore sought; (b) areas geologically hospitable to that type of ore; (c) the location of the area in relation to working, transport, treatment and marketing of the substance mined.

Type of ore

(a) The type of ore sought will depend on the organisation searching. Mining corporations will generally be looking for ore which will be valuable on the world market some years ahead. It takes perhaps five to ten years from the discovery of ore to the first run of ore through the treatment plant. Herein lies a major hazard for private mining finance. On the other hand, a government organisation designed fundamentally to be of service to the community will look for ore from a national point of view. They will consider amongst other things such factors as, for instance, (i) the domestic needs in the country concerned, i.e. needs for power (energy) for public utilities, employment of the people, raw material for existing manufacturing undertakings, defence of the country; (ii) the capability of local personnel and services to mine and treat the ore; (iii) the availability of national money to finance the work; and (iv) the diversification of the national economy generally and, in particular, diversification of the economy of particular areas.

Geologically favourable areas

(b) The choice of geologically favourable areas depends on the availability of general geological information in the country concerned. The amount and usefulness of such data varies greatly from country to country. There is a lack of such general information in many land areas in the world. The reasons are simple. Geology is a field science. Its laboratory is the world in general and even a particular problem covers a large part of the earth's crust - a whole mountain range, a swamp area. Geological units are vast in physical size compared to the units used in experimentation or study by the physicist, chemist, metallurgist, and engineer. Getting the facts to work on is thus a major problem. Moreover to understand the geology, it is necessary to use the knowledge of many sciences. Not only have these had to advance to a state useful to the geologist (and some of them have done this rather slowly), but also co-ordinating effort between the sciences has been a big factor. Perhaps, however, the biggest factor has been that of collecting data from which to understand, map and describe. It is submitted that this is the biggest single technical factor which has delayed mineral exploration activity in the so-termed under-developed areas of the world. There is much that can be done about it. The methods and techniques which can be used, and which are generally described below, apply not only to government planning, but also to private enterprise planning though generally perhaps it is considered that this type of work is the business of government.

Regional Fact-finding and Mapping Methods

5. (a) The systematic search for ore in a country will start as a

priority in that area chosen, from the foregoing factors, as the most promising. The choice will be best made if the regional geology of the country at least is well understood. If the area has to be chosen on meagre geological information, it will still be necessary to know the regional geology of the chosen area before systematic ore search is possible.

(b) Methods of regional geological surveying involve the techniques of field mapping and laboratory study, aerial photography and the interpretation of such photography, airborne geophysics, applied geochemistry, and heavy mineral sampling.

6. Ideally, these techniques should be incorporated into framework of a general fact-finding mapping programme designed and managed by experienced technical people. There should, however, be no thought that there is a unique programme applicable to all areas nor that a programme once initiated, should be so rigid that changes in the light of progress and evidence gathered cannot be made. There are, however, basic technical concepts that could well be adopted and are universally applicable whatever the area:-

(a) Speed in gathering facts.

(b) Practical scope and specification for the mapping.

(c) Consistency in gathering facts and in presentation of these facts.

(d) Consistency in direction and management.

7. Speed is important. This does not mean haste. The pace at which the programme goes will be determined by the amount of effort (man and equipment) that can be put on to it, by the specification (or scope) of the work defined at the outset and by the techniques used in the programme. The pace of the programme should be designed to be fast. We must remember that fact-finding surveying is only the very first step in a long process leading to ore. This means modern techniques must be used. It is really no use such a programme being deliberately designed to take, say, a hundred years. The economy of a country and the potential users of the results of such a programme, be it government agencies or private enterprise, cannot wait that long.

8. (a) The scope of the programme will vary with the area, of course, but it should be defined by the need to produce factual maps of practical use in mining exploration, say, within the next decade, not perfect examples of mapping for museum purposes. Such refinements can come later. They are properly the prerogative of applied research groups (government or private) and will come most economically and logically by virtue of detailed work by many groups of people after broader regional geology has been mapped by the techniques described. Whilst the government geological departments in many parts of the world have set the standards of quality of geological mapping, the time has come when either by widening their scope or by instituting sister organisations, the emphasis should also be on the production of useful factual maps rather than solely on the production of perfect, detailed geological maps. Some governments have accepted this.

(b) For the scope of the mapping programme to be practical, it is implied that the various potential users have been consulted and the scope worked out with them.

9. Consistency in gathering facts is important. It would be inappropriate, for instance, for the geologists, geophysicists or geochemists generally to attempt to work to a degree of detail which cannot be presented on the maps because of scale limitation or to an accuracy which is inconsistent with the accuracy of the topographic maps. It would, for instance, not be sense to use geophysical methods which are designed for detailed problems and not for regional work.

10.(a) Consistency in direction and management is an ideal to be aimed at. Consistency in direction presupposes that the programme fits into a general resources plan which will be pursued throughout the life of the mapping programme and further, that if the overall resources plan is likely to be modified, then the mapping programme is capable of logical modification too. It presupposes that the person, committee or body of men directing the programme is competent and consistent and acts in a way that is acceptable to the users of the maps produced.

(b) Consistency of management implies a simple organisation with competent experienced people in key positions. It implies that the programme will not get side tracked technically on to studying detail outside the aims of the programme.

(c) Overall, both direction and management should have the best possible continuity or else the enthusiasm of the project will drop. Ultimately, it is the personnel involved more than the techniques used which will determine the success of the programme. The morale of these personnel is important.

Base maps and mapping materials

11. The mapping of field detail relies on having a map on which to map. The modern techniques of producing such maps is by photogrammetry. Generally, one would nowadays plan to have airphoto cover of the area fairly early on in the programme. It need not be right at the start, since other work can start before it is obtained. It is probable that, over any area you like to choose, airphoto cover of some sort exists. This may be at a scale and of a quality that can be used for, say, a preliminary photo-geological study or as navigational material for air geophysical flights or location of streams etc. for geochemical field work. Existing airphoto cover can usually be used in some way, but it may, particularly if it is old, be too limited to use for long on the programme.

12.(a) The question of flying new photo-cover may arise. The specification for it will have to be decided on by surveyor, geologist, geochemist. It is hoped a compromise really acceptable to none can be avoided.

(b) Scales of air photography can be anywhere from, say, 1:10,000 to 1:60,000. The popular scale for photo-interpretation is 1:30,000 to 1:40,000. It ought, of course, to be larger than the scale of the final mapping.

(c) The quality and specification of the photography is important. Modern air camera lenses are generally excellent. Modern lenses of six inches and eight and one-quarter inch focal length give very acceptable definition and coverage for the interpreter and field man. The newer super wide angle lenses of, say, three and one-half inch focal lenses and a one hundred and twenty degree angle of view, however, produce some problems for field man and interpreter. It is general to use a nine inch by nine inch format though a seven inch by seven inch format is some times used. It is general to have a forward overlap of sixty per cent for stereoscopic viewing with a twenty-five per cent lateral overlap between runs which should be straight flown and continuous. One expects that the tip and tilt of the photography is kept within good limits of levelling and that the mechanical and electrical parts of the equipment are functioning so that, for instance, consistent overlap and precise focussing is obtained without image movement. The base used for the film itself must be stable enough to be acceptable to photogrammetrists.

(d) The use of colour photography will come - great strides are being made to get correct colour, enable higher flying, reduce processing costs and the like. For the present, the advantages are doubtful. Sometimes colour alone is a disadvantage.

(e) Infra-red photography has been used where standing water and vegetation make normal panchromatic film unacceptable.

(f) The type of topographic maps usual on regional mineral exploration programmes is planimetric (e.g. features not heights) produced by a low, but consistent order of photogrammetric technique, namely slotted template. Consistency in scale is obtained by having a useful number of astrofixes (or better) placed throughout the area. From such a framework not only "line" or "planimetric" maps to act as a basis for data are produced, but also photo-mosaics, found to be most valuable in field work.

(g) For various reasons, the production of controlled maps and mosaics may not be possible. In this case, so-called uncontrolled mosaics are often used. They clearly have disadvantages, not the least of which being duplication and omission of ground detail due to the fact that ground surface is only occasionally truly level.

Photo-interpretation and field work

13. The scope and system used in photo-interpretation varies. It has been generally proved, however, that the best schemes involve the interpreters working not only on the photographs but observing in the field also. A customary programme would involve (a) laboratory pre-field photo-study plus a library study of known data; the photo-study being a rapid one aimed at working out broad features and patterns and pointing up the key points to visit in the field; (b) field study based on (a) to solve problems, develop photo-keys and collect vital information not only in the field, but also available locally, unpublished, in files, in the compilation stage or simply in the local peoples' thoughts; (c) post-field collating, revising, reviewing, deciding, followed by presentation on map and in report. As a guide the following data may be useful:-

> Area 30,000 square miles; scale of photography 1:40,000; number of geologists 7; programme:- four months pre-field, six months in field, six months post-field; final mapping scale 1:50,000.

Regional geophysics

14.(a) In technical circles there is much controversy over the proper use of airborne geophysics, particularly in regional geological mapping programmes. Some hold it should be used as a localised exploration technique or to assist in the solution of particularly geological problems. That is, used over specific (probably small) areas after the basic geological mapping is done. Not until then they claim, can the geophysical survey specification be defined nor the results interpreted in a useful way. Others hold that large areas should be covered automatically (preferably by the same aircraft unit to save expense) by all available methods (e.g. magnetic, electromagnetic, radiometric and possibly gravity) and that the data obtained should be compiled and held against the need to assist in the solution of specific geological or mineral location problems. A third body of opinion holds that regional geology cannot be done thoroughly and rapidly without using air geophysics at an early stage integrated right into the regional geological mapping. It holds further that the storing of uninterpreted geophysical data is wasteful since only when interpreted in geological terms, does it begin to be useful at all to the field geologist. From the writer's experience, the third view is the more correct one. It involves, of course, the closest possible contact between the geophysical, geological and mining people concerned throughout the project. This can be achieved and is being achieved on U.N.S.F. and A.I.D. projects in being now or recently carried out.

(b) It is clear that magnetic and radiometric data obtained by a well designed and controlled air survey and competently interpreted on the basis of even fairly sparse geological data by a team composed of scientists of complementary field disciplines can produce fundamental geological information in remarkable density which is absolutely essential at a very early stage in geological mapping. The very dense framework of geological information given by the method enables the field worker to work from the framework down to the detail and moreover enables him to work much more efficiently and quickly in the field. This concept of establishing the framework first then proceeding to work out the detail within the framework, is accepted as ideal in topographic and geophysical surveying, but has not yet been accepted generally in geological circles. It should be, now there are methods available for doing it.

(c) At the present time, the air magnetic and radiometric methods have been developed and their results understood enough to use them as first line regional geological mapping methods. The air gravity method is in its infancy and the air electromagnetic methods developed so far fall more into the category of methods applicable to special problems and geological situations.

(d) There is much to grasp in the design and conduct of such surveys to get the best results cheaply - for the methods are cheap. Perhaps the ideal sequence for a programme involving air geophysics and geology would be:- (i) Very preliminary photo- and library geological study on which to base the specification of the air geophysical survey. (ii) Design and execution of air geophysical survey. (iii) Interpretation of air geophysical data and initial regional geological field work, running together. (iv) Next stage field geological work with mineral exploration on targets found, running in parallel.

Regional geochemical prospecting

15.(a) Methods of applied geochemistry are well established. Techniques of a regional nature involve soil sampling and stream sediment sampling and cover a wide range of metals. The field work is some times economically speeded by the use of helicopters for transporting men and samples. Care is necessary to see that the capability of the laboratory(ies) used is sufficient to keep pace with the field work. It is also essential to perform preliminary tests called "orientation studies" to define the specification for the geochemical survey. The main thing, of course, is to establish (i) that the method in general will work in the area chosen, and then (ii) that the technique which will be most practical and successful is used.

(b) Data is presented on planimetric maps similar to those used for geology and geophysics. In the field, air photographs giving as they do an abundance of detail, are the best location mapping and recording system.

(c) It is time more thought was given to including regional geochemical prospection methods into regional fact-finding mineral resources mapping programmes.

Heavy mineral sampling

16.(a) Heavy mineral surveys are similar in concept to geochemical stream sediment sampling. The field techniques used are different however. Samples are taken from stream beds where changes in water velocity have given an accumulation of heavy minerals.

(b) Whilst the method has been used during routine field geological mapping in the past, it has been more recently used as a rapid field method to meet a specific mining exploration problem. There is no reason why it could not be integrated into a multi-method fact-finding survey at an early stage of a mineral exploration programme.

Methods of Intensive Mineral Exploration

17.(a) As the results of the systematic regional geological/mineral mapping programme come to hand, areas (targets) for intensive exploration study and effort will be revealed. This is where a wide variety of methods can be employed to assess the potential value of the ore.

(b) Target areas may have been quite precisely defined by the systematic survey or the result may be wider zones of interest. The physical size of the area of the target or zone will dictate to some extent the exploration methods used. The methods applicable are perhaps conveniently grouped into geological, geophysical, geochemical and mineral:-

(i) Geological methods include:- Larger scale field mapping and associated detailed photo-interpretation, involving as it may special air photography and contour mapping. Exploratory drill holes, trenching, pitting and exploratory addits. Structural geological mapping using borehole etc. data.

(ii) Geophysical methods include:- Magnetic - airborne (fixed wing or helicopter) or ground; total field (fluxgate, proton, or other systems) or component (Schmidt balance or Torsion etc.); surface or borehole. Electromagnetic - airborne (fixed wing, helicopter) or ground; horizontal

or vertical loop; Afmag. Induced polarisation. Resistivity (many systems for deep or shallow penetration). Self-potential. Radiometric - airborne (fixed wing or helicopter) or ground; geiger counter or scintillation counter; surface or borehole. Gravity. Seismic - shallow or deep; single, two geophone or multi-channel.

(iii) Geochemical methods would be soil or stream sediment with a definite metal or metals in mind.

(iv) Mineral methods include heavy mineral prospecting; assaying of samples.

(c) Depending on the target size, mineralisation, type, etc., a combination of the methods noted above would be used.

Reporting, storing results and original samples

(d) It is, of course, absolutely essential, if effort is not to be wasted, that all such detailed work is adequately reported by word and map and that samples, drill cores, measurements, etc., with accurate location descriptions, are retained. This is altogether a big organisational problem which should be faced up to. The cost of obtaining data and samples is appreciable and even this alone justifies consideration for retaining such information for review periodically as geological thinking in the area advances.

General Conclusions

18.(a) Methods of mineral exploration are used to the best advantage if they are carried out within the framework of planned programmes - not over-planned or vast programmes, but well conceived, well directed programmes of useful size and scope.

(b) Man power in mineral exploration should be used economically and the results of such effort not wasted for the future. They can be used economically if the exploration programme is well conceived and the methods and techniques used are modern. The results can be of lasting use if they are retained in suitable fashion. It is important but difficult to retain concepts and enthusiasm throughout an exploration programme. This is best done by maintaining continuity of thought through personal contact. It is appropriate in this United Nationsl Conference to note that this aspect must be a major pre-occupation of those in Special Fund and indeed in F.A.O., concerned with designing aid projects. The hope for continued direction, management and continuity of knowledge beyond the time when the aid agency ceases actively on a project has been stressed in recent "Recommendations" by the Managing Director, U.N.S.F. It is an aspect that should rightly be stressed; the difficulty being how to achieve it, particularly in those countries where such a programme is timed often by design to occur when there is a change over from expatriates to nationals in the government departments concerned.

1073 E - Oct.1962 - 1,600

NOTES

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HYDROLOGICAL SERVICES IN THE UAR

by
H.K. Fahmy (M.Sc.)
Director General Nile Control
M.F. Taha (B.Sc., D.I.C.)
Director General Meteorological Department
M.L. El-Ebrashy (B.Sc.)
Assistant Under-secretary, Ministry of Works

PART I.

ORGANIZATION OF METEOROLOGICAL SERVICE

Application of Meteorology for Economical and Industrial Development in the Country:

1. The role of meteorology in the economic developments in the country is becoming more and more important with the application of science and technology for this economic department. It would suffice to illustrate this importance to note that the ECOSOC has drawn the attention of Governments, in its resolution 829(XXXII) to the importance of the establishment of networks of meteorological stations to the economic development of countries. The experience of the UAR in the application of meteorology to the projects of the economic development plan of the country has proved that such an application is an important factor in the achievements of the plan. Many examples can be quoted to demonstrate this fact, the most important of which are the applications of meteorology in the fields of Aviation, Agriculture, Shipping, Development of Water Resources ..... etc.

2. Thus it must be accepted as an established fact in all developing countries, that the establishment of a Meteorological Service is an important point of the Economic Development plan of the Country. First priority should be given to the development of networks of meteorological stations which must start as a matter of urgency because any meteorological study has to be based on accumulated data obtained by those stations over the largest possible period.

The Unification of Meteorological Service under One Administration:

3. The experience of the UAR in organizing meteorological activities has proved that it is essential to have all meteorological activities in the country undertaken by one Administration.

4. Prior to 1947 there were two Meteorological Services in the UAR, the first one under the Ministry of Public Works, the second under the Civil Aviation Department. This situation has led to inefficiency and inconsistency in the provision of meteorological services to various purposes. Such a division of efforts leads also to slow department.

5. In 1947 those two Services were amalgamated together into one Administration VIZ the Meteorological Department, which was made responsible for all meteorological activities in the Country This unification has enabled the Department to develop progressively since that time and to improve the services which it provides to all users of meteorology.

Technical and Administrative Orgnization of the Meteorological Services:

6. The organization of the Meteorological Department of the UAR comprises a Director General, assisted by a Deputy Director General and Directors of the following main Divisions: - Climate Division, Forecasting Division, Stations and Methods of Observations Division, Technical Affairs Division, Telecommunications Division and an Administrative Division.

7. Our experience in this Organization of the Meteorological Department has revealed the following points:

(a) The establishment of a Technical Affairs Division separate from the other specialized technical divisions has proved to be most useful in conducting all the technical activities of the Department in a concerted and coordinated manner. This division is responsible interalia for following up the implementation of international resolutions and recommendations in the field of Meteorology in the UAR. This fact ensures the development of the technical activities of the Department in the right directions and enables it to fulfil its contribution to International Meteorology in an efficient manner.

(b) The need has demonstrated itself for organizing research work in the Meteorological Department. A careful study has been made of this requirement. One solution would be to let every technical division undertake its own research work. This solution has the disadvantage that the meteorologists working in these divisions are overloaded with their operational duties and that there would be no coordination in the research work undertaken by various divisions. On the other hand if a special division is established solely for research work, the research work will be isolated from the practical day-to-day applications which is a disadvantage. The solution reached by the Meteorological Department of the UAR is to establish a Meteorological Institute for research and training as a part of the Meteorological Department, with the assistance of the UN Special Fund. The Organization of this Institute will be such as to provide a continuous flow of meteorologists and knowledge between this Institute and the Technical Divisions of the Department at all levels. In order to activate and encourage research work, a programme of scientific lectures is organised periodically where meteorologists get together and listen to and discuss together results of their own research work or investigations.

(c) Under the present organization, the activities of the Department in the fields of agrometeorology and meteorological instruments are both under the Stations and Methods of Observation Division. Experience has shown that this is not an efficient manner to conduct the activities of the Department in these two important fields, and that it is necessary to establish a separate Division for each of these two branches. The Meteorological Department will start immediately by establishing a special Division for Agrometeorology due to its direct importance to the economic development of the country in the Sector of Agriculture.

(d) It should be the responsiblity of the Meteorological Department solely to undertake meteorological instructions and training to Pilots and all other persons requiring such training e.g. agriculturists, sea men ... etc. This includes laying down syllabli, delivering lectures and training, examinations ... etc. within the framework of standards and Recommended Practices laid down for this purpose by WMO & ICAO or other International Bodies.

Selection of Networks of Meteorological Observing Stations for Different Purposes:

8. The number and distribution of meteorological observing stations of different types should be determined in the light of the provisions of the WMO Technical Regulations and the national considerations concerning the need and practicability of having certain stations at certain places.

9. The establishment of such stations far from inhabited areas where means of living and transport are inadequate gives rise to some difficulties which have to be studied and solved on the basis of local conditions. No one solution can be recommended for general application in all such cases. The Meteorological Department has undertaken, as one of the measures of solving these difficulties to provide housing facilities for the staff working in such stations.

10. The equipment required for each type of meteorological observing stations can be determined with the help of the WMO Guide to Meteorological instruments. There are several manufacturers in different countries for each type of equipment. The choice of the manufacturer from whom the equipment should be ordered depends on many factors some of which are technical concerning the specifications of the instruments and their suitability for certain climatic conditions, and some are non technical such as the availability of currency involved. Developing countries should benefit from the experience of their neighbouring countries with similar climate in the choice of their meteorological instruments and should endeavour to use the same instruments as in adjacent countries. This would facilitate arrangements for training and for obtaining spare parts. The most important point which should be taken care of in this respect is the provision of proper training of personnel on the installation, operation and maintenance of such equipment. This could be done by the means of expert missions and/or fellowships.

11. It has been found necessary to establish a workshop for meteorological instruments for the maintenance, reparation, calibration and standardization of meteorological instruments.

Standards, Qualifications and Training of Field Personnel:

12. The Meteorological Department of the UAR requires the following standards for qualifications and training for each category of meteorological personnel:

(a) Meteorological Observers;

(i) Surface and Pilot Balloon Observers: Secondary School Certificate and a 6 months training course in the Training Centre of the Meteorological Department.

(ii) Radiosonde and Radiowind Observers: Same Qualifications and training as for previous category and an additional training in electronics of six months or more depending on the qualifications, experience and ability of the trainees.

(iii) Agrometeorological Observers: Same qualifications and training as for (a) above and an additional training in the field for few months.

(b) Meteorologists / Forecasters: A university degree (B.Sc.) in Physics and/or Mathematics and a post graduate course of one year in Meteorology. Additionally, training in the job for few months is required.

13. An important point which the Meteorological Department wishes to underline in the light of its experience is that it is indispensable that the meteorologists/forecasters be university graduates. It is dangerous to accept any lower standard for this category which is responsible for highly scientific work on which depends the safety of life and property.

14. Another point which should be given careful consideration by developing countries is the choice of training centres or universities to which they should send their personnel for training. This depends on many factors some of which are technical concerning the standard of the training given in each of these centres or universities; others are non technical such as the languages facilities available. The WMO Publication on training facilities in various countries is very useful in this respect.

Recruitment of Meteorological Personnel in Sufficient Number and of the Required Standards:

15. The experience of the Meteorological Department in the UAR as well as in most other countries has shown very clearly that, as a career, meteorological work, at all levels, is unattractive when compared with others requiring similar qualifications. This is due to the special conditions in meteorological work particularly shift work and work on official public holidays. As a result, difficulties were experienced in most countries to recruit meteorological personnel and also what is even more important, experienced personnel are tempted to leave their posts in Meteorological Services to other more rewarding and less burdensome occupations.

16. This difficulty has been recognized by ICAO and WMO. A joint meeting of those two Organizations for Aeronautical Meteorology in 1954 has issued a recommendation inviting action to solve this difficulty.

17. In the UAR a special allowance has been decided for all levels of meteorological personnel in the hope that this may take meteorological work more attractive.

18. In view of the long training required for all categories of meteorological personnel care should be taken to recruit an adequate number of personnel based on a careful planning of future developments and needs.

Coordination between the Meteorological Services and other National Agencies requiring Meteorological Help and Advice:

19. The nature and scope of the machinery by which meteorological services required by any National Agency are to be provided, depend on the volume of the services required. In important fields such as aviation and agriculture it is necessary to establish special sections in the Meteorological Department to deal with their requirements. In addition , it is sometimes necessary to establish a permanent committee comprising representatives of meteorology

and the agency requiring meteorological services; such a committee would be responsible for laying down policy to be followed in the provision of meteorological services in the agency concerned.

20. In the AUR, such a committee exists for Agrometeorological Activities. For meteorological services to aviation, there is a special section of the Meteorological Department responsible for this particular aspect. This section maintains close contact with aeronautical personnel.

21. For other cases where the meteorological services required are not voluminous, it would suffice for organizing the provision of such services to have occasional meetings or contacts between the people concerned. The arrangements which are thus agreed upon would be executed by the Meteorological Offices for general purposes.

Policy Recommended for the Running and Operation of a Meteorological Telecommunications Network:

22. Meteorological observations taken at any place cannot be useful unless they are promptly disseminated to all Meteorological Offices collecting such observations for analysis and preparation of forecasts.

23. Thus the establishment of an adequate telecommunications network for the rapid collection and dissemination of meteorological observations is an indispensible requirement in meteorological activities.

24. The first step in organizing such a telecommunications network is the establishment of an internal network of telecommunications over which reports of observations taken at individual stations in the country could be collected in the national centre of the country. This internal network could comprise direct telephone, W/T circuits, L/L circuits, LTT circuits. It is not necessary that all such circuits be exclusive for the collection of meteorological observations; common users circuits can also be relied upon.

25. The second step is to organize a national meteorological broadcast by W/T or RTT in accordance with the specifications laid down by the WMO. The purpose of this broadcast is to transmit the collective observations of all the country to adjacent countries and to the sub-continental centres to which the WMO has assigned the responsibility of collecting the national broadcasts in a specified area and retransmitting them by RTT with a higher power for the benefit of more distant countries.

26. The World Wide Organization of meteorological Broadcasts comprises not only the two above mentioned types of broadcasts (National and Sub-Continental), but also Continental and Hemispherical Broadcasts. The purpose of the Continental Broadcast is to transmit collective reports pertaining to a whole Region to neighbouring region. The Hemispherical Broadcasts are responsbile for the collection and dissemination of meteorological data required for the preparation of Hemispherical Charts.

27. National Broadcasts or other alternative means for disseminating national collective reports are arranged by each country. The countries responsible for other types of broadcasts are designated by the WMO.

28. In addition to this broadcasting system, there exists certain Point-to-point network of RTT W/T circuits between countries in one Region and between countries in different Regions to supplement the broadcasting system.

29. The experience of the Meteorological Department of the UAR has shown that the best manner to organize meteorological telecommunications is to entrust its technical aspects to the State Administration responsible for telecommunications; the administration aspects to be undertaken by the Meteorological Department.

The most fruitful use of UNEPTA and the UN Special Fund in the field of Meteorology:

30. The Meteorological Department of the UAR has derived much benefit from the UNEPTA, by obtaining the services of number of experts and grants of fellowships to a number of meteorologists of the Department.

31. Such assistance would be most useful when it is carefully planned and executed. The most important experience that should be pointed out in this connection is the necessity of appointing a counterpart (from the country) to any expert who is appointed in the country. This counterpart should be prepared to take over from the expert, all his responsibilities at the end of his mission. Without this counterpart, the services of any expert can be of no value at the end of his mission. Great stress should be made to train the maximum possible number of nationals while the expert is in the country. It should also be mentioned that expert missions should have a limited period. It has been expressed by the WMO Executive Committee that normally expert missions to one country should be terminated within five years unless special circumstances required and justify prolongation beyond that period.

32. The efforts of experts provided under the UNEPTA should be devoted solely to training local personnel and they should undertake no operational work. For help in operational duties Developing Countries may benefit from the OPEX scheme of the United Nations whereby they can obtain services of experts especially for operational duties.

33. The value of training seminars which are frequently organized under the UNEPTA is very great. Our experience has shown that the meteorologists who attend such seminars increase considerably their knowledge and skill in their respective fields.

34. As for the UN Special Fund, the Meteorological Department did not yet start execution of any projects with its assistance. The only experience it has is in the planning of a project for the establishment of a Meteorological Institute, with the assistance of the Special Fund, as of a part of the Economic Development Plan of the Country.

PART II.

ORGANIZATION OF HYDROLOGICAL SERVICE

General Organization:

35. Some of the activities of this service have given under A.3. 2.1., the staff should consist of three categories:

(a) University graduates in civil engineering with special training in hydrology form the 1st category staff. The terms given to the posts will be those used in the UAR. The inspector should have at least 15 years experience and undertakes the general supervision. The deputy looks after the personnel and assists the inspector in the technical matters. The director of works - 10 years

experience - supervises the field and office work and directs the research through two assistants who, also undertakes the checking of all records and observations. The junior engineer should be qualified for field observations including; first order surveying, checking of gauge; discharge observations; silt sampling and rating current meters. The UAR will be willing to undertake the training of any staff.

(b) Computers: Secondary School graduates with sound mathematical training or technical school graduates. One group undertakes: entry of gauges, checking and computation; the second for checking discharge sheets, entry and computations.

(c) Draftsmen and administrative staff will be as local requirements.

Hydrological Service:

36. This service should consist of the following:

(a) Gauge Office: Receives the more important gauge reading by wire. The reading of remote and less important sites as well. Before entry into register all gauges are plotted on diagram to detect any mistakes. The correct readings are entered into 3 different registers kept by 3 different computers: 56-day, 10-day and monthly means are computed and checked on the three registers. They will then be ready for publications.

(b) Discharge Office: For the important station discharge observation results are wired. These are used for urgent work such as forecasts. Discharge sheets are later checked and a gauge-discharge curve is plotted for every station. From means of gauges, corresponding discharges are read on this curve. 10-day monthly means and yearly totals are published.

(c) Forecasting Office: This undertakes forecasting of river supply and flood stages from the above data collected. Forecasts are used for filling and emptying of reservoirs and distribution of natural supply plus storage.

(d) Rainfall and evaporation Office: Field data are received in the form of monthly and half monthly returns showing the amount and the number of rainy days. Data published consists of monthly and yearly totals and number of rainy days.

(e) Laboratory: A small laboratory may be useful to find out the quantity of suspended matter and the mechanical analysis of samples for the study of silt transportation and scouring and silting in reservoirs and river channel.

PART III.

CO-ORDINATION BETWEEN THE METEOROLOGICAL AND HYDROLOGICAL SERVICES

The Importance of Cooperation and Coordination between the Meteorological and Hydrological services in Problems of Common between Hydrology and Meteorology:

37. The common grounds between Hydrology and Meteorology cover parameters such as precipitation, evaporation, humidity, temperature, evapotranspiration, soil moisture. Those meteorological parameters

are required in the study of the hydrological cycle and their evaluation is essential in water resource studies. Thus it is essential to maintain coordination and cooperation between the hydrological and Meteorological services to ensure satisfying the requirements of both services. The absence of such a co-ordination would lead to duplication of efforts and non-homogenity in distribution of observing stations, instruments used and methods of observations, which would mislead technical studies in both science.

38. There is a certain philosophy that such a coordination is best provided for, by bringing Hydrology and Meteorology together under one Department. Experience has shown that this is not a good arrangement; it lowers the level of activities in both branches. The required co-ordination can be very well ensured by maintaining close liaison between the two Services which would take form of periodical joint meetings or a permanent Committee.

Ways and Means of Provision of Meteorological Data for Hydrology with Special References to the Exchange of Data and Network Design:

39. The design of networks for the measurement and study of those parameters in the hydrological cycle which involve meteorological considerations, including the desirable spatial distribution of stations and the time interval between observations for various purposes, have to be studied in the light of the hydrological requirements for those parameters. The Hydrological Service would state its requirements whereas the Meteorological Service would provide advice on the location of stations and undertake the execution of the networks.

40. The extent to which the exchange of data required for hydrological purposes varies from one country to another according to the scope and nature of the hydrological problems of the country.

41. In the UAR, where the main hydrological problems are those related to the River Nile, it is important to exchange data between countries on the River. The Meteorological Service with its comprehensive telecommunications facilities provide the means for effecting the required exchange.

42. It should be noted that the two questions of networks design and exchange of data do not have internationally agreed concepts. The Commission for Hydrological Meteorology of the WMO has looked into those two questions during its first session Washington 1961 and could not reach a conclusion and decided therefore to establish Working Groups to study them.

911 E - Oct.1962 - 1,600

E/CONF.39/A/142
18 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.3.2.1

Japan

DISCHARGE MEASUREMENTS BY USING A FLOAT

By Toshio TAKENOUCHI,
Public Works Research Institute,
Ministry of Construction, Japan

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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DISCHARGE MEASUREMENTS BY USING A FLOAT

by
Toshio Takenouchi
Public Works Research Institute, Ministry of Construction, Japan.

I. ADVANTAGES AND DISADVANTAGES OF FLOAT MEASUREMENT

1. Japan is a mountainous country where rivers are so steep in gradient that they flow at a high velocity, carrying away huge quantities of matter during flood time. For this reason the Price current meter is not suitable for velocity measurements during flood time, and a float is used at almost all gauging stations. Fortunately bamboo is so easily available everywhere in Japan that a bamboo float as shown in Figure III is used for this purpose in most instances.

2. Close attention should be paid to various points where the measurement of velocity is made by using a bamboo float, taking into account the following advantages of the float :

(a) Immerging a float in a stream is easy where there is a bridge
(b) A simple immerging device is good enough when gauging at a site where the river is narrow in width
(c) A velocity close enough to mean velocity is obtainable in gauging with a long float.

3. The flow velocity gauged with a float is a mean value for a certain distance along a river. Accordingly the conditions of the section may be a matter of discussion.

(a) It would be impossible to find a straight course of stream where the cross section is in a constant or in a uniform variation all the way through the course.
(b) The flow down course of a float as well would often be not perpendicular to the cross section. In such a case the area to be assigned to the float is hard to estimate for the calculation of flow velocity.
(c) In flow velocity measurement by means of a float the cross section of a stream is not measured at the same time. The cross section surveyed after or before a flood is applied to a flood discharge calculation . It is considerably different from its value during a flood. As a result, some error would be inevitable in such a calculation.

4. We do not think that flow measurement by means of a float is satisfactory for flood flow observation. The author and his associates are developing a new type of current meter for depth and velocity, as show in Figure IV, which gives precise flood discharge. This new meter is expected to be completed soon.

II. ANALYSIS OF REDUCTION COEFFICIENT

5. Theoretical analysis

There have been two typical papers published in this country on the motion of a float in a stream as quoted hereafter.

(a) Mononobe's reduction formula :—

Based upon the assumption that a float placed in a stream behaves relative motion with the flow, applying Bazin and Humphrey's curvilineal formula for flow velocity distribution, a correlation equation was introduced to find the flow down velocity of float. The reduction coefficient α denoting the ratio of the mean flow velocity of flow distribution curve to the flow down velocity of a float can be represented by the following formula.

$$\alpha = 1 - \frac{12}{c}\left\{1 - 2.5(n-0.3)^2\right\}$$

when

c is Chezy's velocity coefficient and n is the ratio of the depth of the immersion of a float to the depth of water.

(b) Aki's reduction formula :—

Based on the assumption that a float placed in a stream follows just the same movement as current, solving a equation of motion with Kozeny's turbulent coefficient put in it, a curvilineal equation of current velocity distribution was introduced. The reduction coefficient α of float is represented by the following formula.

$$\alpha = \frac{C}{C + \frac{20}{3} - \frac{20}{3}n} \qquad (a = 0)$$

$$= \frac{C}{C + \frac{1}{3} + 2n - \frac{20}{3}n^2} \qquad (a = 0.1)$$

$$= \frac{C}{C + \frac{4}{3} + 4n - \frac{20}{3}n^2} \qquad (a = 0.2)$$

$$= \frac{C}{C + \frac{7}{3} + 6n - \frac{20}{3}n^2} \qquad (a = 0.3)$$

when

a is the position of maximum velocity from surface.

6. Experimental analysis.

(a) Velocity distribution :—

The velocity distribution of a stream during flood time was observed by means of a current meter for depth and velocity as mentioned above. The meter has a device for automatically recording velocity distribution with it gently immerged up to river bed from water surface. Fig I shows the flow velocity distribution as recorded at a gauging station on the stream with 0.8 m water depth and 3 m/sec mean velocity during a small flood. This gauging station has some 1/300 grade of stream and a river bed made of coarse gravel and sand. In contrast to such test findings the flow velocity distribution in a concrete channel is far more uniform.

(b) Shape of river bed :—

The shape of river bed at a certain cross section of a stream was surveyed intermittently during a flood time. Depth of water was measured with a 100 kg weight immerged from a cable car. Fig. II shows that the river bed is much scoured during flood time.

III. SIMPLIFIED REDUCTION COEFFICIENT

7. The gauging of flood flow in this country is carried out in such circumstances where floats have to be applied for gauging flow velocity during a flood. In order to help ease the preparation and work of gauging and flow calculation, it was found effective that such floats be limited to several types as to fix the reduction coefficients of flow velocity to a constant value. The applicable water depths, the length of floats and the reduction coefficients are in the relation as shown in the Table 1.

TABLE 1.

Applicable water depth (m)	Length of float to be used (m)	Reduction coefficient
- 0.7	surface float	0.85
0.7 - 1.3	0.5	0.88
1.3 - 2.6	1.0	0.91

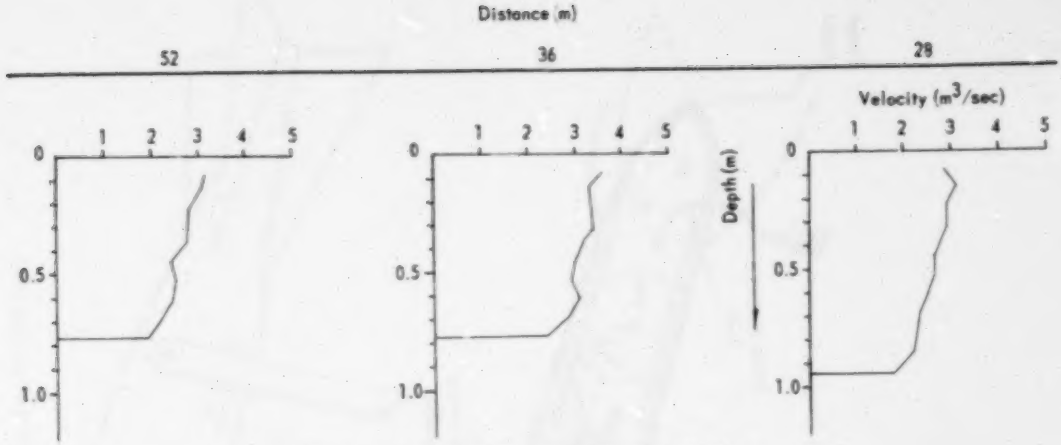

Fig. I - Example of flow velocity distribution

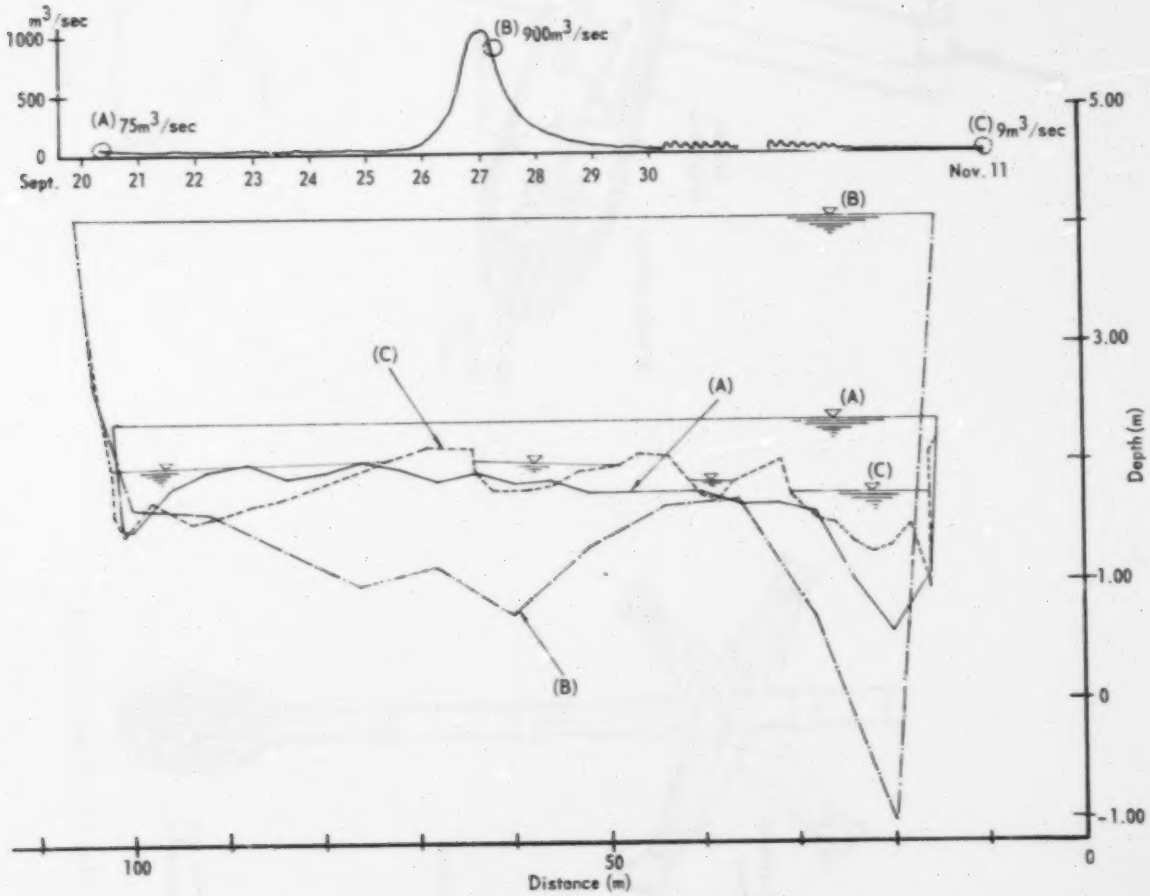

Fig. II - Example of scouring of river bed

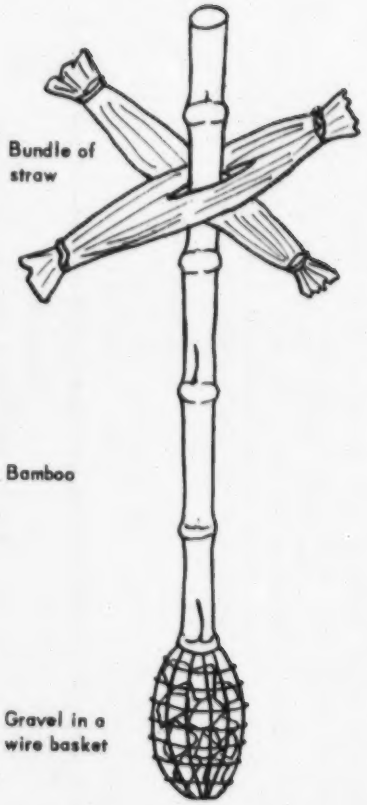

Fig. III - Bamboo Float

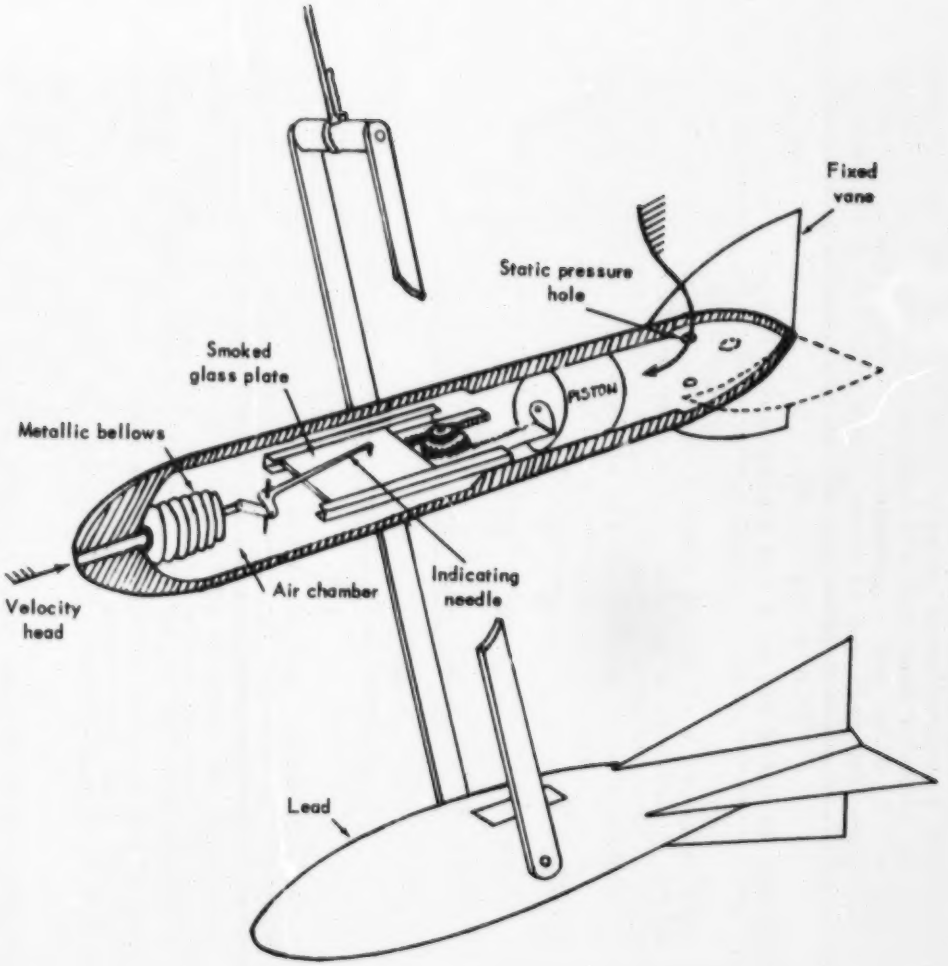

Fig. IV - New currentmeter

1017 E - Oct.1962 - 1,600

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

USE OF PRESTRESSED CONCRETE ELEMENTS IN WATER SUPPLY SYSTEMS

RESULTING GAINS IN FOREIGN EXCHANGE AND INDUSTRIAL DEVELOPMENT

by Peter J. Doanides
Professor, Urban Engineering,
Athens Technological Institute.

INTRODUCTION

1. The use of prestressed concrete for water storage reservoirs and water aqueducts has started in the United States since the early days of use of prestressed concrete.

2. As the knowledge of the design and the available materials improved, prestressed concrete tanks and pipes have become competitive and are used very extensively.

3. Whereas at the beginning such applications were mostly in highly industrialized countries, they are now used more and more in developing countries as they present, in addition to savings in cost, the advantage in saving in foreign exchange and are helping in the industrial development by the formation of local industries that can easily be adapted for other uses in the construction field.

THEORETICAL ASPECTS

4. Both prestressed pipes and tanks are structurally cylindrical shells. Since the main load they have to resist is internal pressure, prestressing in both cases consists of a circumferential wrapping of wires (or cables) that pre-compresses the concrete cylindrical shell whilst empty. Thus, when the pipes carry water under pressure or the tank is full, the concrete core instead of being under tension is decompressed. The design in both instances has to supply enough prestressing so as to have the concrete decompressed to zero stresses at maximum loading after the creep of steel and shrinkage of concrete have taken place.

5. Both prestressed pipes and prestressed tanks have a concrete core precompressed by wrapping high tensile wire around it and then an outside protective concrete or mortar coating to protect the wire from corrosion.

PRESTRESSED CONCRETE PIPES

6. The economic advantage gained with prestressed concrete pipes is based on the fact that the internal pressure of the water is taken by high tensile wire instead of mild or medium grade steel. High tensile wire is now produced by the industry at only twice the cost of regular steel whilst it has a useful tensile strength six to eight times higher than the strength of regular steel. The cost advantage, however, obtained in favour of high tensile wire, is reduced by the need of using high tensile wire in combination with concrete (a concrete core to be compressed by the high tensile wire and an outside concrete or mortar protective coating), while regular steel pipe requires only protection from corrosion. However, experience has shown that even in countries with high labour rates, the cost of the concrete required is less than the saving in cost of steel gained through the use of high tensile wire.

7. This cost advantage is particularly high for large diameter pipes. For diameters of less than 60 cms. the cost of producing the concrete pipes, that will be prestressed with high tensile wire, increases to the extent that, depending on local conditions of costs of materials, it might upset the saving and make the steel pipe more economical. For the above reasons, prestressed pipes are particularly advantageous for large diameters, preferably exceeding 1 m. where the cost differential is much larger.

8. For countries importing their steel requirements from abroad, prestressed concrete in substitution to steel pipes becomes even more important, as the cost of steel is equivalent to the need of expenditure in foreign exchange whilst the cost of concrete (labour and the biggest part of the cost of concrete materials) is in local currency.

9. The manufacture of prestressed concrete pipes can be done near the site of their actual use, thus eliminating the cost of transportation.

10. A prestressed concrete pipe manufacturing plant can easily be operated by local personnel and thus assist in the industrial development of the country. After the completion of the manufacture of the pipes required, the plant can be used for the manufacture of additional concrete pipes or other precast prestressed concrete elements and thus assist in the needs of the building industry of the area.

11. Until now, in most cases the manufacture of prestressed concrete pipes was entrusted to one of a few specialized international firms with experience in this field.

12. The writer was instrumental in having prestressed concrete pipes manufactured by a local firm for the Athens aqueduct.(1)

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(1) Doanides, P. J.: Prestressed pressure pipe lines for the Athens Aqueduct. "Civil Engineering" of the American Society of Civil Engineers, p. 653-657 (1958).

THE PRESTRESSED CONCRETE PIPE MANUFACTURING PLANT FOR THE EXTENSION OF THE WATER SUPPLY OF TEHRAN

13. Another very interesting case successfully tried out in Iran, is the Pipe Manufacturing Plant for the prestressed pipes required for the water supply of Greater Tehran.

14. The Tehran Water Board, instead of entrusting the manufacture of prestressed pipes to a foreign firm, decided to ask internationally for tenders for the supply and erection of a prestressed concrete pipe manufacturing plant. This plant, now completed, is operated departmentally by the Tehran Water Board who use their own engineers and local labour.

15. This plant is required for the manufacture of approximately 30,000 l.m. of 2m inside diameter low pressure pipes to carry the water from the newly built Karaje Dam to the water treatment plant located just West of Tehran, and approximately 28,000 l.m. of high pressure pipes with diameters of 1.85, 1.70, 1.40 and 1.35 meters required as water distribution mains from the treatment plant to the city.

16. The savings obtained from the substitution of steel with prestressed concrete have been estimated as follows:

a. Cost savings including all materials, labour and full depreciation of all equipment 18%

b. Savings in foreign exchange including again all materials imported and produced locally, cost of labour and supervision, including foreign experts and full depreciation of all imported and locally manufactured equipment 44%

17. The plant is at present producing 600 tons of pipes per day and employs a total number of 350 men: This number includes 16 graduate Iranian Engineers and approximately 60 operators of equipment, welders and other skilled workers, the remainders being unskilled labourers.

18. The plant has been so planned and designed as to be able to produce the pipes that will be required for the extension of the water supply of Greater Tehran. It can also be used with small changes for the manufacture of sewer pipes and other precast prestressed elements.

PRESTRESSED RESERVOIRS

19. Prestressed concrete is also used for water storage reservoirs.

20. In view of the internal water pressure, the most economical form for water reservoirs is the cylinder. The cylindrical wall shell is subject to tensile stresses which justify the use of steel plates as material. With prestressed concrete, a concrete cylindrical wall shell is precompressed by high tensile wire wound under tension around the shell or applied in the form of circumferential prestressing cables that apply a compressive load to the concrete cylindrical shell. Again, like in the case of prestressed pipes, when the tank is filled with water, the concrete is decompressed rather than placed under tension and the water pressure is resisted by this combined decompression of the concrete and a slight increase in tension of the prestressing wire.

21. Water storage reservoirs are also built with regular reinforced concrete, however, in view of the fact that concrete resists very poorly tensile stresses, reinforced concrete non prestressed reservoirs require considerably larger quantities of both concrete, as well as reinforcing steel.

22. The special equipment required for the construction of prestressed circular reservoirs is relatively inexpensive and fairly simple to operate. It would therefore be most desirable to see this method of construction more widely used in countries under development, as besides savings in costs, it reduces the need in foreign exchange and increases the use of local materials and local labour.

23. It is also possible to substitute the cast in situ cylindrical concrete wall with precast concrete panels and thus reduce the requirements in forms. This is particularly desirable for countries where timber or steel forms are to be imported from abroad.

24. An interesting example is the two precast prestressed water storage reservoirs built in 1954 in Sasolburg, South Africa.[2] [3] These tanks have each a capacity of 7,500,000 imperial gallons (35,000 cu. ms) and a diameter of 280 ft. (85.50 mts.) - See figure

CONCLUSION

25. The progress of the technology of prestressed concrete makes possible the use of this composite material in the manufacture of large diameter pressure pipes and water reservoirs, in countries under development.

26. The use of prestressed concrete is very desirable as it not only reduces the cost of the project, but in addition, assists by saving in foreign exchange requirements and by encouraging the formation of local building industries.

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(2) Doanides, P. J.: Some Notes on Precast Prestressed Tanks. "Transactions of the South African Institution of Civil Engineers". p. 207-238 (1955).

(3) Doanides, P. J.: Big prestressed concrete tanks built with precast panels. "Civil Engineering" - American Society of Civil Engineers, p. 562-564 (1955).

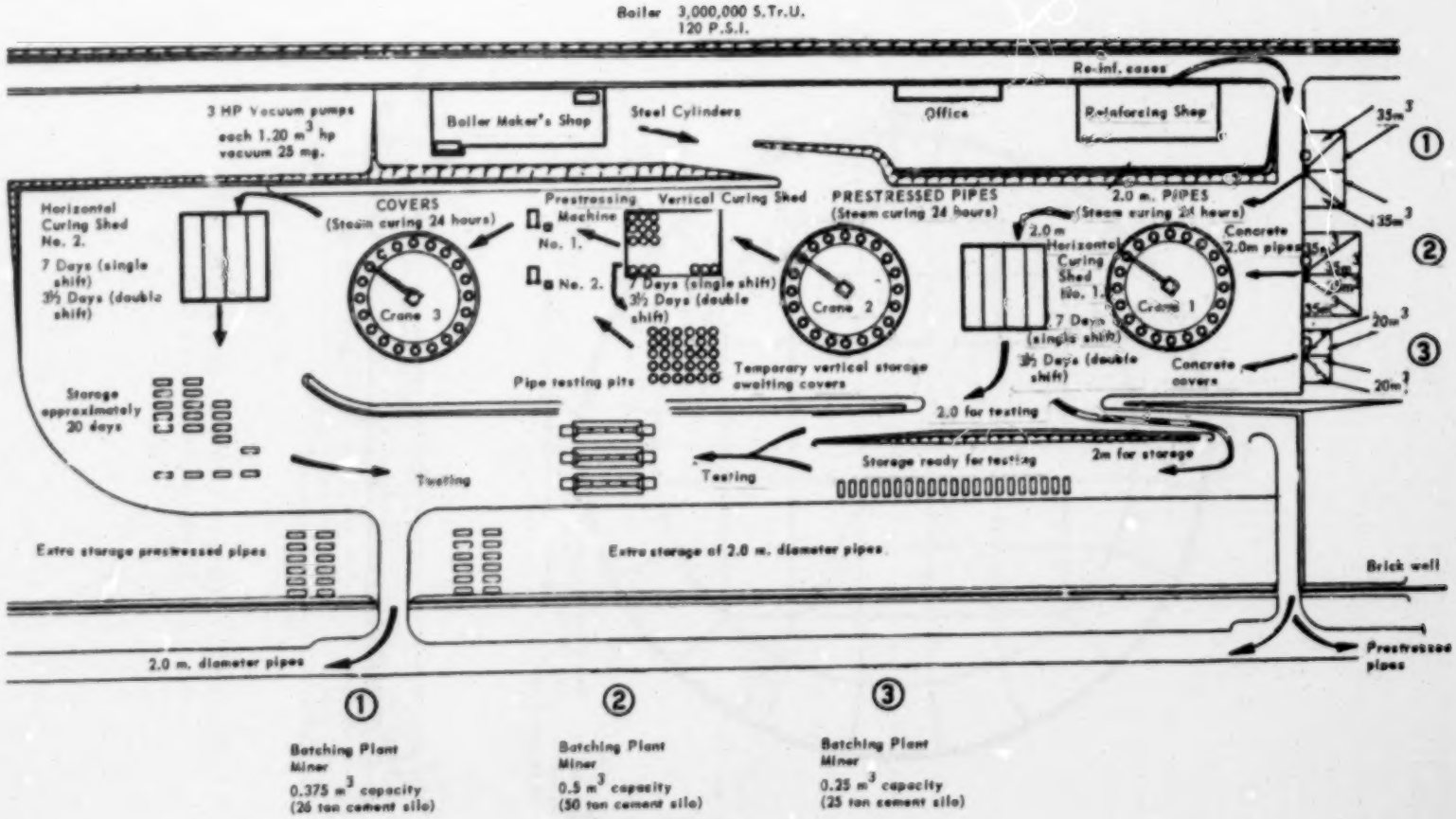

Figure 1 - Casting Yard Layout, Tehran

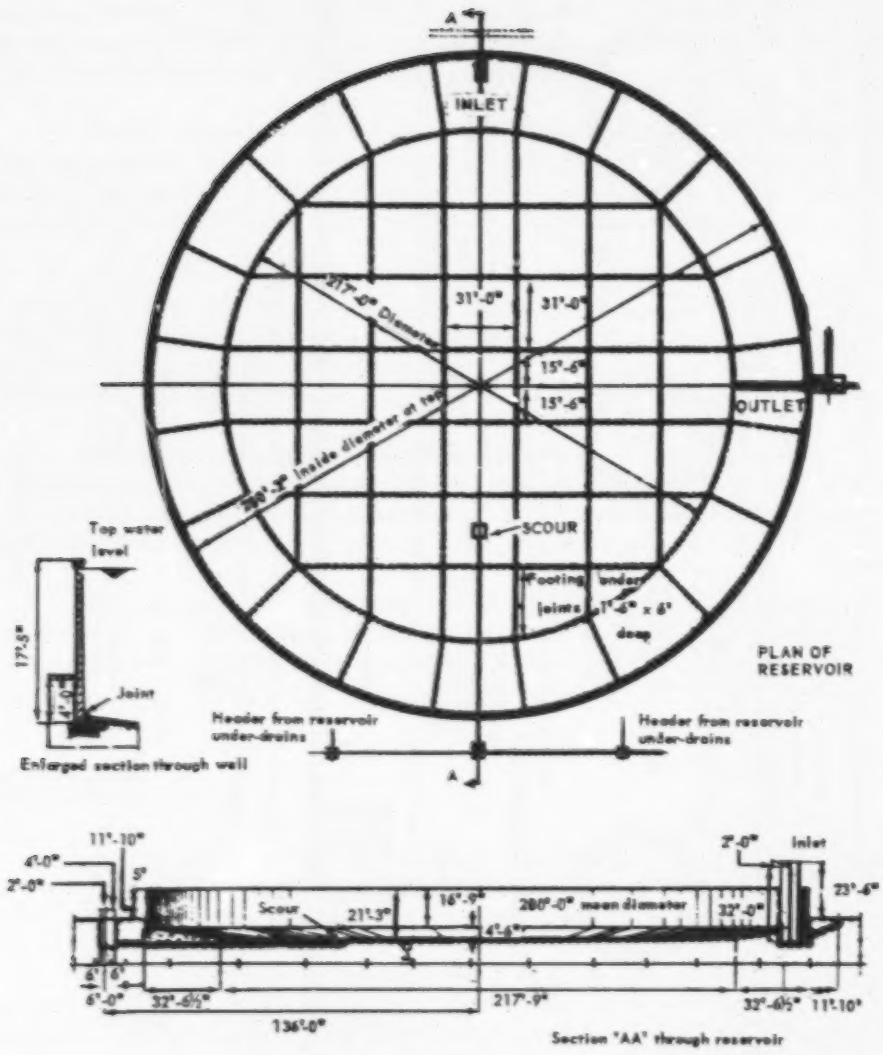

Figure 2 - Plan and elevation of 9 1/2 million U. S. gallon reservoirs at Sasol

862 E - Nov.1962 - 1,600